Downstream FEC Proposal for EPoC

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FEC Proposal for EPOC Downstream

- DVB-C2 Bit interleaved coded modulation (BICM)
  - 16200-length shorter LDPC code + BCH outer code
  - Column twisted Bit interleaver.
- This is mature and has been proven to work in HFC environment
- We propose to use code rate 8/9 as the primary code rate for all SNR
- We support all square constellations from QAM16 to QAM4096
- We extend DVB-C2 to non-square or odd constellations (128/512/2048)
- We define column-twisted bit interleavers for non-square constellations
- We combine successive modulations with a fixed 50:50 ratio to get 1.5 dB SNR step size in the spectral efficiency graph, using 8/9 code rate only (this will be explained in detail)
- We propose to include code rates 7/9 and 6/9 with minimal extra complexity for extreme burst conditions

Extension to Non-Square Constellations

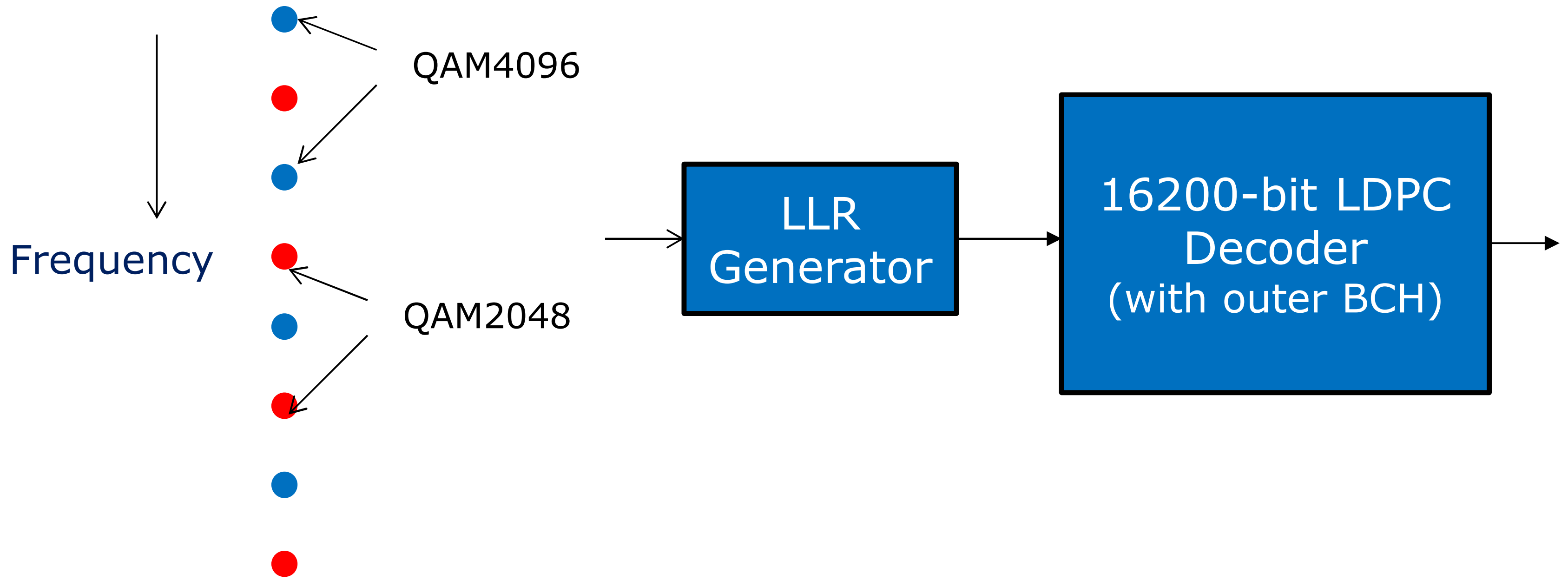
- DVB-C2 supports square QAM constellations only, but has six LDPC code rates
- Even with all these rates, some operating points are separated by about 3 dB along the SNR axis of the spectral efficiency graph. Also the operating points are not uniformly spaced.
- It is preferable to achieve a SNR point using a lower order modulation and higher code rate than higher order modulation and lower code rate
  - Because of losses (e.g. phase noise) in the demodulator
- Furthermore, higher code rates are more hardware efficient than lower code rates because of fewer number of parity check equations
- Hence our aim has been to use only the highest code rate of 8/9
- To achieve a 3 dB SNR resolution in the spectral efficiency graph with 8/9 code rate we have defined non-square constellations & associated column-twisted bit interleavers
- Then we go up and down the spectral efficiency graph in 3 dB steps by changing only the modulation, keeping code rate fixed
- See later for the way of achieving 1.5 dB SNR step

Detailed Specification of Odd or Non-square QAM Constellations

- Back-up material of this presentation contains:
  - Details of column twisted bit interleavers for QAM128/512/2048
  - Details of constellation mappings
  - Modifications to the tables of the DVB-C2 specification to include odd or non-square constellations

Idea for Achieving 1.5 dB SNR Resolution

- In each OFDM symbol
  - We make 50% of the data carriers square-QAM, say QAM4096
  - We make other 50% of data carriers non-square-QAM, say QAM2048

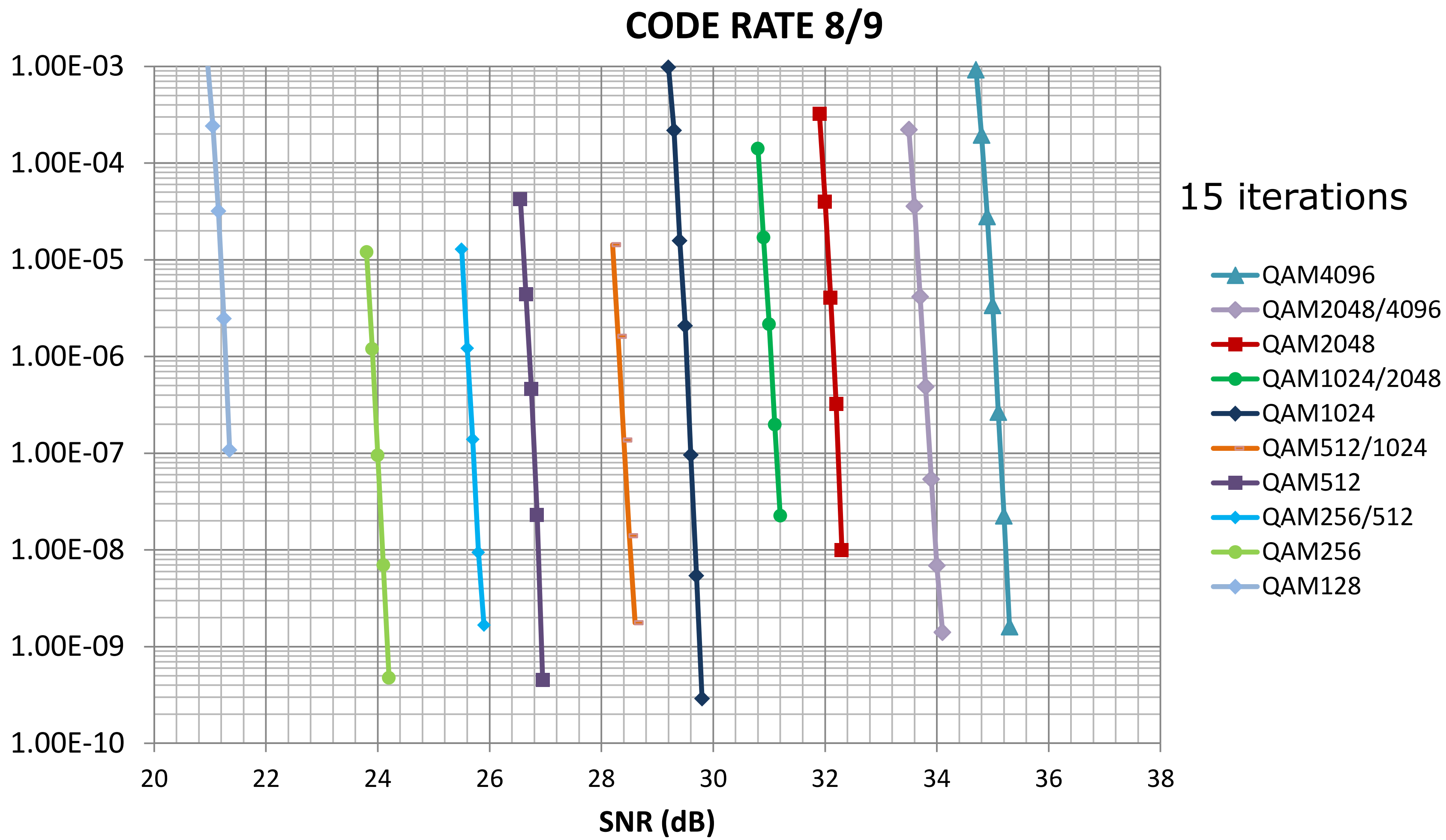


- So the spectral efficiency of the new modulation is halfway between QAM4096 and QAM2048
- We show that the SNR requirement is also halfway between the SNR requirements of QAM4096 and QAM2048
- Same applies to QAM-1024/2048, 512/1024, 256/512 & 128/256

Combined Modulation Definition

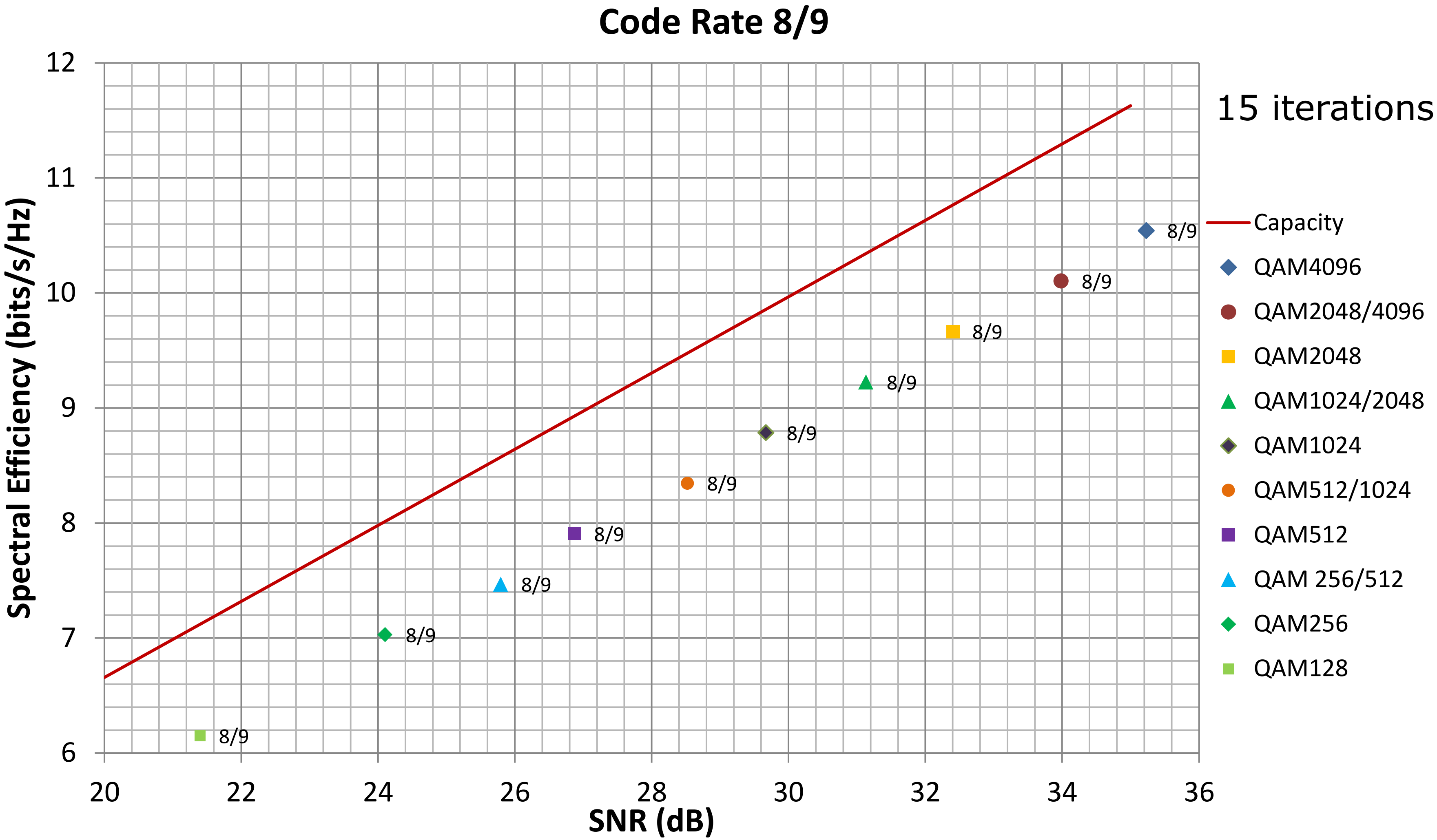
- The only purpose of the combined modulation idea is to achieve approximate 1.5 dB SNR resolution in the spectral efficiency graph
- For example, to get the mid-point between QAM2048 and QAM4096 we combine these modulations 50:50 within one LDPC codeword
- LDPC-coded bits to OFDM carrier mapping has a fixed pattern and ratio:
  - QAM2^{N+1} carriers occupy locations 0, 2, 4, …
  - QAM2^{N} carriers occupy locations 1, 3, 5, …
- This bits to carrier mapping happens after LDPC encoding and bit interleaving but before time and frequency interleaving
- This fixed mapping is signalled by the same parameter that is used to signal the QAM constellation. It is an "effective constellation" halfway between QAM2^{N+1} and QAM2^{N}
- Note also that a LDPC codeword always maps onto an integer number of OFDM sub-carriers. This means that in some instances there could be unused bits in the last sub-carrier, that are discarded by receiver.
- For combined modulation we use the bit interleaver defined for QAM4096

AWGN Performance



- Shows square and non-square constellations, as well as those in between
- The performance has been measured by limiting iteration count to 15

Spectral Efficiency Graph

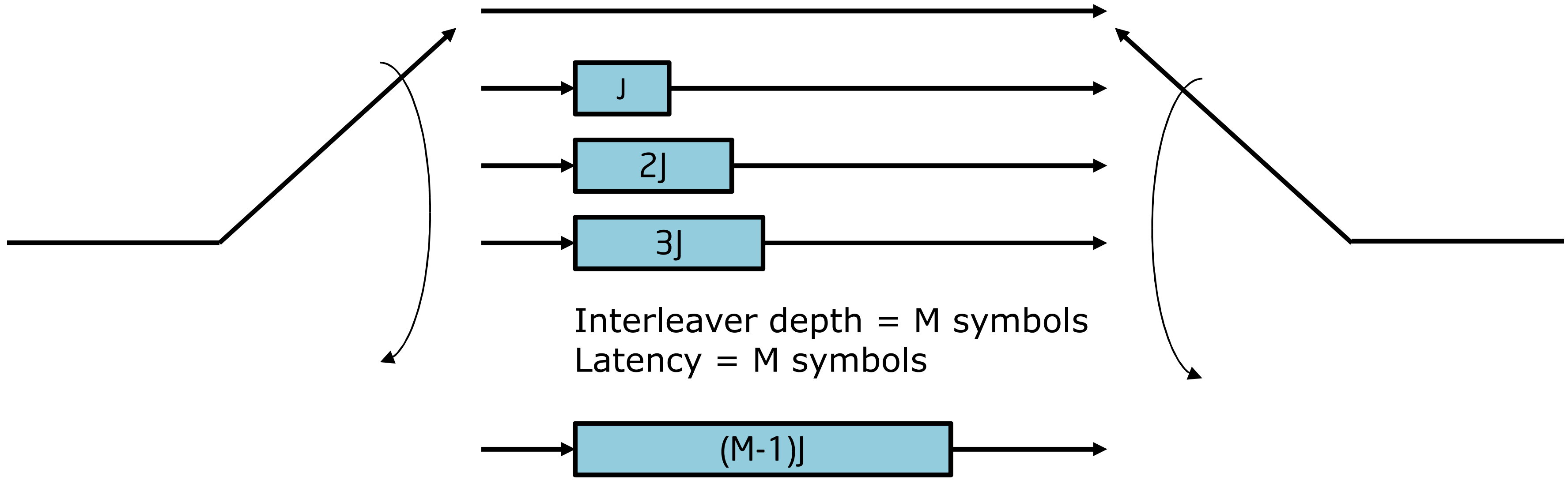


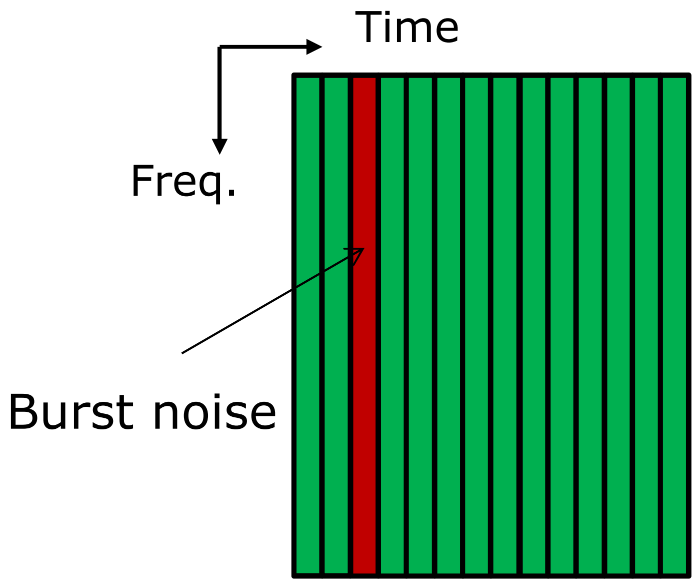
- All results obtained using the simplest LDPC code rate of 8/9
- Operating points are more uniformly spaced than in the DVB-C2 standard which uses six code rates

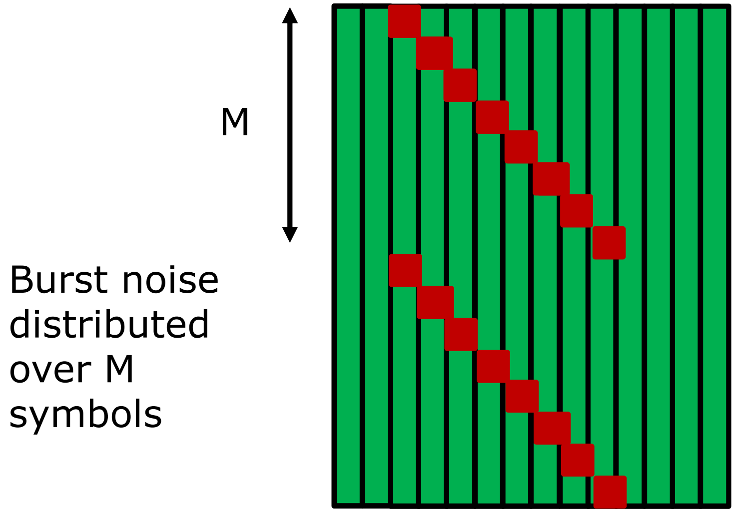
Burst Performance

- We propose using a convolutional time interleaver operating on OFDM sub-carriers to mitigate broadband burst noise
- Different sub-carriers of each OFDM symbol delayed by different amounts
- Burst errors in the channel can impact one (or even two) OFDM symbols
- Convolutional de-interleaver will spread this burst over M symbols
- M is the depth of the interleaver in OFDM symbols
- Value of M limited by the tolerable latency and memory size
- We propose making the interleaver depth programmable with a maximum value of 32
- Use of convolutional sub-carrier-level interleaving gives the most memory efficient hardware architecture

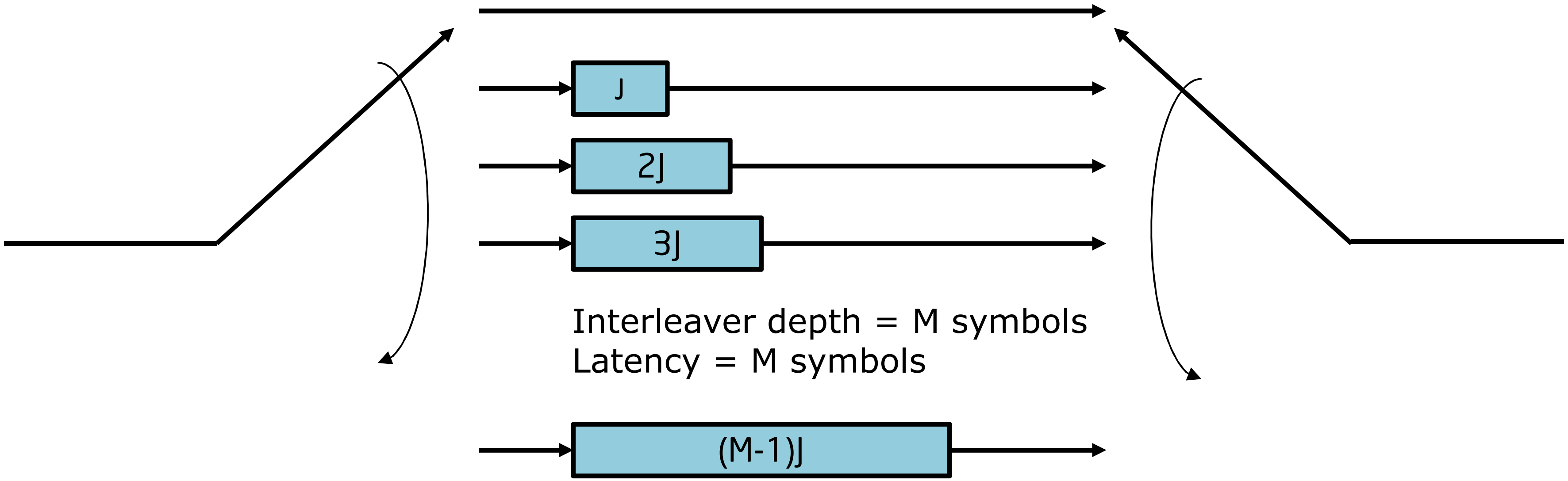
Time Interleaver Structure







Time Interleaver Parameter J



- Let N be the number of data carriers in the OFDM symbol. N may not be a multiple of M
- Define J = (N/M)
- But (N/M) may be a fraction. Then J is the next highest integer
- Append (JM – N) dummy carriers to make the symbol length a multiple of M
- Enter the dummy carriers into the interleaver, but discard at interleaver output
- But during implementation dummy carriers not written or read

Burst Noise Performance Simulations

Burst Condition	Interleaver depth
+20 dB SNR burst of 16 us impacting Two symbols	10-12 symbols with code rate 8/9
-inf SNR burst of erasing One complete symbol	12 symbols with code rate 8/9
-inf SNR burst of erasing Two complete symbols	26 symbols with code rate 8/9
-inf SNR burst of erasing Two complete symbols	18 symbols with code rate 7/9
-inf SNR burst of erasing Two complete symbols	8 symbols with code rate 6/9

- Hence we propose including code rates 7/9 and 6/9 code rates as back-up for low latency applications operating in extreme burst noise conditions

Conclusions

- We propose DVB-C2 FEC with
  - 16200-length LDPC code + BCH outer code
  - Column twisted Bit interleaver.
- We propose to use code rate 8/9 as the primary code rate for all SNR
- Support all square (even) QAM constellations from QAM16 to QAM4096
- Extended to non-square (odd) QAM constellations QAM128, 512 and 2048
- With column-twisted bit interleavers defined for non-square constellations
- We propose combining successive modulations with fixed 50:50 ratio and fixed odd-even locations within an FEC codeword to achieve 1.5 dB resolution along the SNR axis of the spectral efficiency graph
- We propose to include code rates 7/9 and 6/9 with minimal extra complexity for extreme burst conditions

Proposed Motion

- Propose that the DVB-C2 Forward Error Correction scheme, with the following modifications, be adopted as the downstream Forward Error Correction Scheme of EPOC
  - Use a single primary code rate of 8/9 to cover all SNR conditions
  - Use back-up rates 7/9 and 6/9 for extreme burst noise conditions
  - Include odd order QAM constellations with associated column-twisted bit interleavers
  - Provide an option to map carriers with successive QAM constellations onto one LDPC codeword, via the bit interleaver defined for QAM4096, but with fixed 50:50 ratio and fixed odd-even locations

❑ Moved by:
❑ Seconded by:
❑ Technical motion (>=75%)
❑ Yes / No / Abstain


THANK YOU!

Details of Specification

The following pages contain changes to the DVB-C2 specification to incorporate non-square constellations 128, 512 and 1024

ETSI EN 302 769 V1.2.1 (2011-04) Digital Video Broadcasting (DVB); Frame structure channel coding and modulation for a second generation digital transmission system for cable systems (DVB-C2)

Column-twisted Bit Interleaver for Non-Square QAM

Since 16,200 is not divisible by 7 and 11, for QAM-128 and QAM-2048 constellations, zeros shall be appended after parity interleaving and prior to column-twist interleaving at the end of the block (5 zero bits for QAM-128 and 3 zero bits for QAM-2048 added after the 16,200th bit), thus the extended block of 16,205 bits or 16,203 bits shall be interleaved by the column-twist interleaver for QAM-128 and QAM-2048 respectively.

The following rows are added to table 6 of DVB-C2 specification.

Modulation	Rows N_r		Columns N_c
	Nldpc = 64 800	Nldpc = 16 200	
128QAM	-	2 315	7
512QAM	-	1 800	9
2048QAM	-	1 473	11

The following rows are added to table 7(a) of DVB-C2 specification.

Modulation	Columns N_c	N_{ldpc}	Twisting parameter t_c											
			Col. 0	1	2	3	4	5	6	7	8	9	10	11
128 QAM	7	16200	0	1	2	2	2	3	3	-	-	-	-	-
512 QAM	9	16200	0	1	2	3	5	6	7	9	11	-	-	-
2048 QAM	11	16200	0	0	0	0	0	3	3	4	4	4	4	-

Constellation Mappings for Non-Square QAM

QAM128

	-11	-9	-7	-5	-3	-1	1	3	5	7	9	11
11			66	67	75	74	10	11	3	2		
9			64	65	73	72	8	9	1	0		
7	69	68	84	85	81	80	16	17	21	20	4	5
5	71	70	86	87	83	82	18	19	23	22	6	7
3	79	78	94	95	91	90	26	27	31	30	14	15
1	77	76	92	93	89	88	24	25	29	28	12	13
-1	109	108	124	125	121	120	56	57	61	60	44	45
-3	111	110	126	127	123	122	58	59	63	62	46	47
-5	103	102	118	119	115	114	50	51	55	54	38	39
-7	101	100	116	117	113	112	48	49	53	52	36	37
-9			96	97	105	104	40	41	33	32		
-11			98	99	107	106	42	43	35	34		

The mapping is given in decimal number format and the symbols are arranged on an odd integer grid.

QAM512

y \ x	-23	-21	-19	-17	-15	-13	-11	-9	-7	-5	-3	-1	1	3	5	7	9	11	13	15	17	19	21	23
23					264	265	269	268	300	301	297	296	40	41	45	44	12	13	9	8				
21					266	267	271	270	302	303	299	298	42	43	47	46	14	15	11	10				
19					258	259	263	262	294	295	291	290	34	35	39	38	6	7	3	2				
17					256	257	261	260	292	293	289	288	32	33	37	36	4	5	1	0				
15	276	277	273	272	336	337	341	340	324	325	321	320	64	65	69	68	84	85	81	80	16	17	21	20
13	278	279	275	274	338	339	343	342	326	327	323	322	66	67	71	70	86	87	83	82	18	19	23	22
11	286	287	283	282	346	347	351	350	334	335	331	330	74	75	79	78	94	95	91	90	26	27	31	30
9	284	285	281	280	344	345	349	348	332	333	329	328	72	73	77	76	92	93	89	88	24	25	29	28
7	316	317	313	312	376	377	381	380	364	365	361	360	104	105	109	108	124	125	121	120	56	57	61	60
5	318	319	315	314	378	379	383	382	366	367	363	362	106	107	111	110	126	127	123	122	58	59	63	62
3	310	311	307	306	370	371	375	374	358	359	355	354	98	99	103	102	118	119	115	114	50	51	55	54
1	308	309	305	304	368	369	373	372	356	357	353	352	96	97	101	100	116	117	113	112	48	49	53	52
-1	436	437	433	432	496	497	501	500	484	485	481	480	224	225	229	228	244	245	241	240	176	177	181	180
-3	438	439	435	434	498	499	503	502	486	487	483	482	226	227	231	230	246	247	243	242	178	179	183	182
-5	446	447	443	442	506	507	511	510	494	495	491	490	234	235	239	238	254	255	251	250	186	187	191	190
-7	444	445	441	440	504	505	509	508	492	493	489	488	232	233	237	236	252	253	249	248	184	185	189	188
-9	412	413	409	408	472	473	477	476	460	461	457	456	200	201	205	204	220	221	217	216	152	153	157	156
-11	414	415	411	410	474	475	479	478	462	463	459	458	202	203	207	206	222	223	219	218	154	155	159	158
-13	406	407	403	402	466	467	471	470	454	455	451	450	194	195	199	198	214	215	211	210	146	147	151	150
-15	404	405	401	400	464	465	469	468	452	453	449	448	192	193	197	196	212	213	209	208	144	145	149	148
-17					384	385	389	388	420	421	417	416	160	161	165	164	132	133	129	128				
-19					386	387	391	390	422	423	419	418	162	163	167	166	134	135	131	130				
-21					394	395	399	398	430	431	427	426	170	171	175	174	142	143	139	138				
-23					392	393	397	396	428	429	425	424	168	169	173	172	140	141	137	136				

QAM2048 Quadrant 1

	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47
47	160	161	165	164	180	181	177	176	48	49	53	52	36	37	33	32								
45	162	163	167	166	182	183	179	178	50	51	55	54	38	39	35	34								
43	170	171	175	174	190	191	187	186	58	59	63	62	46	47	43	42								
41	168	169	173	172	188	189	185	184	56	57	61	60	44	45	41	40								
39	136	137	141	140	156	157	153	152	24	25	29	28	12	13	9	8								
37	138	139	143	142	158	159	155	154	26	27	31	30	14	15	11	10								
35	130	131	135	134	150	151	147	146	18	19	23	22	6	7	3	2								
33	128	129	133	132	148	149	145	144	16	17	21	20	4	5	1	0								
31	256	257	261	260	276	277	273	272	336	337	341	340	324	325	321	320	64	65	69	68	84	85	81	80
29	258	259	263	262	278	279	275	274	338	339	343	342	326	327	323	322	66	67	71	70	86	87	83	82
27	266	267	271	270	286	287	283	282	346	347	351	350	334	335	331	330	74	75	79	78	94	95	91	90
25	264	265	269	268	284	285	281	280	344	345	349	348	332	333	329	328	72	73	77	76	92	93	89	88
23	296	297	301	300	316	317	313	312	376	377	381	380	364	365	361	360	104	105	109	108	124	125	121	120
21	298	299	303	302	318	319	315	314	378	379	383	382	366	367	363	362	106	107	111	110	126	127	123	122
19	290	291	295	294	310	311	307	306	370	371	375	374	358	359	355	354	98	99	103	102	118	119	115	114
17	288	289	293	292	308	309	305	304	368	369	373	372	356	357	353	352	96	97	101	100	116	117	113	112
15	416	417	421	420	436	437	433	432	496	497	501	500	484	485	481	480	224	225	229	228	244	245	241	240
13	418	419	423	422	438	439	435	434	498	499	503	502	486	487	483	482	226	227	231	230	246	247	243	242
11	426	427	431	430	446	447	443	442	506	507	511	510	494	495	491	490	234	235	239	238	254	255	251	250
9	424	425	429	428	444	445	441	440	504	505	509	508	492	493	489	488	232	233	237	236	252	253	249	248
7	392	393	397	396	412	413	409	408	472	473	477	476	460	461	457	456	200	201	205	204	220	221	217	216
5	394	395	399	398	414	415	411	410	474	475	479	478	462	463	459	458	202	203	207	206	222	223	219	218
3	386	387	391	390	406	407	403	402	466	467	471	470	454	455	451	450	194	195	199	198	214	215	211	210
1	384	385	389	388	404	405	401	400	464	465	469	468	452	453	449	448	192	193	197	196	212	213	209	208

QAM2048 Quadrant 2

	-47	-45	-43	-41	-39	-37	-35	-33	-31	-29	-27	-25	-23	-21	-19	-17	-15	-13	-11	-9	-7	-5	-3	-1
47									1056	1057	1061	1060	1076	1077	1073	1072	1200	1201	1205	1204	1188	1189	1185	1184
45									1058	1059	1063	1062	1078	1079	1075	1074	1202	1203	1207	1206	1190	1191	1187	1186
43									1066	1067	1071	1070	1086	1087	1083	1082	1210	1211	1215	1214	1198	1199	1195	1194
41									1064	1065	1069	1068	1084	1085	1081	1080	1208	1209	1213	1212	1196	1197	1193	1192
39									1032	1033	1037	1036	1052	1053	1049	1048	1176	1177	1181	1180	1164	1165	1161	1160
37									1034	1035	1039	1038	1054	1055	1051	1050	1178	1179	1183	1182	1166	1167	1163	1162
35									1026	1027	1031	1030	1046	1047	1043	1042	1170	1171	1175	1174	1158	1159	1155	1154
33									1024	1025	1029	1028	1044	1045	1041	1040	1168	1169	1173	1172	1156	1157	1153	1152
31	1104	1105	1109	1108	1092	1093	1089	1088	1344	1345	1349	1348	1364	1365	1361	1360	1296	1297	1301	1300	1284	1285	1281	1280
29	1106	1107	1111	1110	1094	1095	1091	1090	1346	1347	1351	1350	1366	1367	1363	1362	1298	1299	1303	1302	1286	1287	1283	1282
27	1114	1115	1119	1118	1102	1103	1099	1098	1354	1355	1359	1358	1374	1375	1371	1370	1306	1307	1311	1310	1294	1295	1291	1290
25	1112	1113	1117	1116	1100	1101	1097	1096	1352	1353	1357	1356	1372	1373	1369	1368	1304	1305	1309	1308	1292	1293	1289	1288
23	1144	1145	1149	1148	1132	1133	1129	1128	1384	1385	1389	1388	1404	1405	1401	1400	1336	1337	1341	1340	1324	1325	1321	1320
21	1146	1147	1151	1150	1134	1135	1131	1130	1386	1387	1391	1390	1406	1407	1403	1402	1338	1339	1343	1342	1326	1327	1323	1322
19	1138	1139	1143	1142	1126	1127	1123	1122	1378	1379	1383	1382	1398	1399	1395	1394	1330	1331	1335	1334	1318	1319	1315	1314
17	1136	1137	1141	1140	1124	1125	1121	1120	1376	1377	1381	1380	1396	1397	1393	1392	1328	1329	1333	1332	1316	1317	1313	1312
15	1264	1265	1269	1268	1252	1253	1249	1248	1504	1505	1509	1508	1524	1525	1521	1520	1456	1457	1461	1460	1444	1445	1441	1440
13	1266	1267	1271	1270	1254	1255	1251	1250	1506	1507	1511	1510	1526	1527	1523	1522	1458	1459	1463	1462	1446	1447	1443	1442
11	1274	1275	1279	1278	1262	1263	1259	1258	1514	1515	1519	1518	1534	1535	1531	1530	1466	1467	1471	1470	1454	1455	1451	1450
9	1272	1273	1277	1276	1260	1261	1257	1256	1512	1513	1517	1516	1532	1533	1529	1528	1464	1465	1469	1468	1452	1453	1449	1448
7	1240	1241	1245	1244	1228	1229	1225	1224	1480	1481	1485	1484	1500	1501	1497	1496	1432	1433	1437	1436	1420	1421	1417	1416
5	1242	1243	1247	1246	1230	1231	1227	1226	1482	1483	1487	1486	1502	1503	1499	1498	1434	1435	1439	1438	1422	1423	1419	1418
3	1234	1235	1239	1238	1222	1223	1219	1218	1474	1475	1479	1478	1494	1495	1491	1490	1426	1427	1431	1430	1414	1415	1411	1410
1	1232	1233	1237	1236	1220	1221	1217	1216	1472	1473	1477	1476	1492	1493	1489	1488	1424	1425	1429	1428	1412	1413	1409	1408

QAM2048 Quadrant 3

	-47	-45	-43	-41	-39	-37	-35	-33	-31	-29	-27	-25	-23	-21	-19	-17	-15	-13	-11	-9	-7	-5	-3	-1
-1	1744	1745	1749	1748	1732	1733	1729	1728	1984	1985	1989	1988	2004	2005	2001	2000	1936	1937	1941	1940	1924	1925	1921	1920
-3	1746	1747	1751	1750	1734	1735	1731	1730	1986	1987	1991	1990	2006	2007	2003	2002	1938	1939	1943	1942	1926	1927	1923	1922
-5	1754	1755	1759	1758	1742	1743	1739	1738	1994	1995	1999	1998	2014	2015	2011	2010	1946	1947	1951	1950	1934	1935	1931	1930
-7	1752	1753	1757	1756	1740	1741	1737	1736	1992	1993	1997	1996	2012	2013	2009	2008	1944	1945	1949	1948	1932	1933	1929	1928
-9	1784	1785	1789	1788	1772	1773	1769	1768	2024	2025	2029	2028	2044	2045	2041	2040	1976	1977	1981	1980	1964	1965	1961	1960
-11	1786	1787	1791	1790	1774	1775	1771	1770	2026	2027	2031	2030	2046	2047	2043	2042	1978	1979	1983	1982	1966	1967	1963	1962
-13	1778	1779	1783	1782	1766	1767	1763	1762	2018	2019	2023	2022	2038	2039	2035	2034	1970	1971	1975	1974	1958	1959	1955	1954
-15	1776	1777	1781	1780	1764	1765	1761	1760	2016	2017	2021	2020	2036	2037	2033	2032	1968	1969	1973	1972	1956	1957	1953	1952
-17	1648	1649	1653	1652	1636	1637	1633	1632	1888	1889	1893	1892	1908	1909	1905	1904	1840	1841	1845	1844	1828	1829	1825	1824
-19	1650	1651	1655	1654	1638	1639	1635	1634	1890	1891	1895	1894	1910	1911	1907	1906	1842	1843	1847	1846	1830	1831	1827	1826
-21	1658	1659	1663	1662	1646	1647	1643	1642	1898	1899	1903	1902	1918	1919	1915	1914	1850	1851	1855	1854	1838	1839	1835	1834
-23	1656	1657	1661	1660	1644	1645	1641	1640	1896	1897	1901	1900	1916	1917	1913	1912	1848	1849	1853	1852	1836	1837	1833	1832
-25	1624	1625	1629	1628	1612	1613	1609	1608	1864	1865	1869	1868	1884	1885	1881	1880	1816	1817	1821	1820	1804	1805	1801	1800
-27	1626	1627	1631	1630	1614	1615	1611	1610	1866	1867	1871	1870	1886	1887	1883	1882	1818	1819	1823	1822	1806	1807	1803	1802
-29	1618	1619	1623	1622	1606	1607	1603	1602	1858	1859	1863	1862	1878	1879	1875	1874	1810	1811	1815	1814	1798	1799	1795	1794
-31	1616	1617	1621	1620	1604	1605	1601	1600	1856	1857	1861	1860	1876	1877	1873	1872	1808	1809	1813	1812	1796	1797	1793	1792
-33									1536	1537	1541	1540	1556	1557	1553	1552	1680	1681	1685	1684	1668	1669	1665	1664
-35									1538	1539	1543	1542	1558	1559	1555	1554	1682	1683	1687	1686	1670	1671	1667	1666
-37									1546	1547	1551	1550	1566	1567	1563	1562	1690	1691	1695	1694	1678	1679	1675	1674
-39									1544	1545	1549	1548	1564	1565	1561	1560	1688	1689	1693	1692	1676	1677	1673	1672
-41									1576	1577	1581	1580	1596	1597	1593	1592	1720	1721	1725	1724	1708	1709	1705	1704
-43									1578	1579	1583	1582	1598	1599	1595	1594	1722	1723	1727	1726	1710	1711	1707	1706
-45									1570	1571	1575	1574	1590	1591	1587	1586	1714	1715	1719	1718	1702	1703	1699	1698
-47									1568	1569	1573	1572	1588	1589	1585	1584	1712	1713	1717	1716	1700	1701	1697	1696

QAM2048 Quadrant 4

	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47
-1	896	897	901	900	916	917	913	912	976	977	981	980	964	965	961	960	704	705	709	708	724	725	721	720
-3	898	899	903	902	918	919	915	914	978	979	983	982	966	967	963	962	706	707	711	710	726	727	723	722
-5	906	907	911	910	926	927	923	922	986	987	991	990	974	975	971	970	714	715	719	718	734	735	731	730
-7	904	905	909	908	924	925	921	920	984	985	989	988	972	973	969	968	712	713	717	716	732	733	729	728
-9	936	937	941	940	956	957	953	952	1016	1017	1021	1020	1004	1005	1001	1000	744	745	749	748	764	765	761	760
-11	938	939	943	942	958	959	955	954	1018	1019	1023	1022	1006	1007	1003	1002	746	747	751	750	766	767	763	762
-13	930	931	935	934	950	951	947	946	1010	1011	1015	1014	998	999	995	994	738	739	743	742	758	759	755	754
-15	928	929	933	932	948	949	945	944	1008	1009	1013	1012	996	997	993	992	736	737	741	740	756	757	753	752
-17	800	801	805	804	820	821	817	816	880	881	885	884	868	869	865	864	608	609	613	612	628	629	625	624
-19	802	803	807	806	822	823	819	818	882	883	887	886	870	871	867	866	610	611	615	614	630	631	627	626
-21	810	811	815	814	830	831	827	826	890	891	895	894	878	879	875	874	618	619	623	622	638	639	635	634
-23	808	809	813	812	828	829	825	824	888	889	893	892	876	877	873	872	616	617	621	620	636	637	633	632
-25	776	777	781	780	796	797	793	792	856	857	861	860	844	845	841	840	584	585	589	588	604	605	601	600
-27	778	779	783	782	798	799	795	794	858	859	863	862	846	847	843	842	586	587	591	590	606	607	603	602
-29	770	771	775	774	790	791	787	786	850	851	855	854	838	839	835	834	578	579	583	582	598	599	595	594
-31	768	769	773	772	788	789	785	784	848	849	853	852	836	837	833	832	576	577	581	580	596	597	593	592
-33	640	641	645	644	660	661	657	656	528	529	533	532	516	517	513	512								
-35	642	643	647	646	662	663	659	658	530	531	535	534	518	519	515	514								
-37	650	651	655	654	670	671	667	666	538	539	543	542	526	527	523	522								
-39	648	649	653	652	668	669	665	664	536	537	541	540	524	525	521	520								
-41	680	681	685	684	700	701	697	696	568	569	573	572	556	557	553	552								
-43	682	683	687	686	702	703	699	698	570	571	575	574	558	559	555	554								
-45	674	675	679	678	694	695	691	690	562	563	567	566	550	551	547	546								
-47	672	673	677	676	692	693	689	688	560	561	565	564	548	549	545	544								

The following rows are added to table 8 of DVB-C2 specification.

LDPC block length (N_{LDPC})	Modulation mode	ηMOD	Number of output Data Cells
16 200	128QAM	7	2 315
	512QAM	9	1 800
	2048QAM	11	1 473

The following rows are added to table 9 of DVB-C2 specification.

Modulation	N_{LDPC}	Number of sub-streams, $N_{substreams}$
128QAM	16200	7
512QAM	16200	9
2048QAM	16200	11

The following rows are added to table 10(a) and 10(b) of DVB-C2 specification.

Modulation format	**128QAM (N_{LDPC} = 16200)**						
Input bit-number, di mod Nsubstreams	0	1	2	3	4	5	6
Output bit-number, e	6	5	4	1	2	3	0

Modulation format	**512QAM (N_{LDPC} = 16200)**								
Input bit-number, di mod Nsubstreams	0	1	2	3	4	5	6	7	8
Output bit-number, e	8	7	6	1	2	3	4	5	0

Modulation format	**2048QAM (N_{LDPC} = 16200)**										
Input bit-number, di mod Nsubstreams	0	1	2	3	4	5	6	7	8	9	10
Output bit-number, e	10	9	8	7	2	3	4	5	6	1	0

The following rows are added to table 13 of DVB-C2 specification.

Modulation	Normalization
128QAM	$f_q = \frac{z_q}{\sqrt{82}}$
512QAM	$f_q = \frac{z_q}{\sqrt{330}}$
2048QAM	$f_q = \frac{z_q}{\sqrt{1322}}$