Broadband Data Book

Scientific Atlanta

THE BROADBAND DATABOOK

Transmission Network Systems
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Lawrenceville, GA 30042
Telephone 770 236 7000

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NOTES ON THE REPRESENTATION OF NUMBERS

Throughout this publication, numbers representing quantities (as distinct from dates) are printed using the conventions of English-speaking countries. That is to say, the decimal point is represented by a period (.) and numbers greater than one thousand have their digits ordered in groups of three, with a comma (,) separating each group.

Thus, the number one million, two hundred and thirty-four thousand, five hundred and sixty-seven point eight nine is written as:

1,234,567.89

It should be noted that the use of the period and the comma is reversed in many European countries. To avoid confusion, the convention originated by ISO (International Standards Organization) and IEC (International Electrotechnical Commission) is sometimes used. This recommends the use of the comma as an indicator of the decimal point, and a space instead of a comma to separate the groups of three digits in large numbers. By this convention, the example given above becomes:

1 234 567,89

Note, however, that the date (year) is written without commas or separators.

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FREQUENCY CHARTS

CATV channels

North America

EIA channel designation		Standard		Incremental		Harmonic	
new	old	Video	Audio	Video	Audio	Video	Audio
T7	none	7.0000	11.5000	NA	NA	NA	NA
T8	none	13.0000	17.5000	NA	NA	NA	NA
T9	none	19.0000	23.5000	NA	NA	NA	NA
T10	none	25.0000	29.5000	NA	NA	NA	NA
T11	none	31.0000	35.5000	NA	NA	NA	NA
T12	none	37.0000	41.5000	NA	NA	NA	NA
T13	none	43.0000	47.5000	NA	NA	NA	NA
2	2	55.2500	59.7500	55.2625	59.7625	54.0027	58.5027
3	3	61.2500	65.7500	61.2625	65.7625	60.0030	64.5030
4	4	67.2500	71.7500	67.2625	71.7625	66.0033	70.5033
1	A-8	NA	NA	73.2625	77.7625	72.0036	76.5036
5	5	77.2500	81.7500	79.2625	83.7625	78.0039	82.5039
6	6	83.2500	87.7500	85.2625	89.7625	84.0042	88.5042
95	A-5	91.2500	95.7500	91.2625	95.7625	90.0045	94.5045
96	A-4	97.2500	101.7500	97.2625	101.7625	96.0048	100.5048
97	A-3	103.2500	107.7500	103.2625	107.7625	102.0051	106.5051
98	A-2	109.2750	113.7750	109.2750	113.7750	Cannot lock to comb	
99	A-1	115.2750	119.7750	115.2750	119.7750	ref: refer to FCC regs.	
14	A	121.2625	125.7625	121.2625	125.7625	120.0060	124.5060
15	B	127.2625	131.7625	127.2625	131.7625	126.0063	130.5063
16	C	133.2625	137.7625	133.2625	137.7625	132.0066	136.5066
17	D	139.2500	143.7500	139.2625	143.7625	138.0069	142.5069
18	E	145.2500	149.7500	145.2625	149.7625	144.0072	148.5072
19	F	151.2500	155.7500	151.2625	155.7625	150.0075	154.5075
20	G	157.2500	161.7500	157.2625	161.7625	156.0078	160.5078
21	H	163.2500	167.7500	163.2625	167.7625	162.0081	166.5081
22	I	169.2500	173.7500	169.2625	173.7625	168.0084	172.5084
7	7	175.2500	179.7500	175.2625	179.7625	174.0087	178.5087
8	8	181.2500	185.7500	181.2625	185.7625	180.0090	184.5090
9	9	187.2500	191.7500	187.2625	191.7625	186.0093	190.5093
10	10	193.2500	197.7500	193.2625	197.7625	192.0096	196.5096
11	11	199.2500	203.7500	199.2625	203.7625	198.0099	202.5099
12	12	205.2500	209.7500	205.2625	209.7625	204.0102	208.5102
13	13	211.2500	215.7500	211.2625	215.7625	210.0105	214.5105
23	J	217.2500	221.7500	217.2625	221.7625	216.0108	220.5108
24	K	223.2500	227.7500	223.2625	227.7625	222.0111	226.5111
25	L	229.2625	233.7625	229.2625	233.7625	228.0114	232.5114
26	M	235.2625	239.7625	235.2625	239.7625	234.0117	238.5117
27	N	241.2625	245.7625	241.2625	245.7625	240.0120	244.5120
28	O	247.2625	251.7625	247.2625	251.7625	246.0123	250.5123
29	P	253.2625	257.7625	253.2625	257.7625	252.0126	256.5126
30	Q	259.2625	263.7625	259.2625	263.7625	258.0129	262.5129
31	R	265.2625	269.7625	265.2625	269.7625	264.0132	268.5132
32	S	271.2625	275.7625	271.2625	275.7625	270.0135	274.5135
33	T	277.2625	281.7625	277.2625	281.7625	276.0138	280.5138
34	U	283.2625	287.7625	283.2625	287.7625	282.0141	286.5141

CATV channels

North America (cont'd)

EIA channel designation		Standard		Incremental		Harmonic	
new	old	Video	Audio	Video	Audio	Video	Audio
35	V	289.2625	293.7625	289.2625	293.7625	288.0144	292.5144
36	W	295.2625	299.7625	295.2625	299.7625	294.0147	298.5147
37	AA	301.2625	305.7625	301.2625	305.7625	300.0150	304.5150
38	BB	307.2625	311.7625	307.2625	311.7625	306.0153	310.5153
39	CC	313.2625	317.7625	313.2625	317.7625	312.0156	316.5156
40	DD	319.2625	323.7625	319.2625	323.7625	318.0159	322.5159
41	EE	325.2625	329.7625	325.2625	329.7625	324.0162	328.5162
42	FF	331.2750	335.7750	331.2750	335.7750	330.0165	334.5165
43	GG	337.2625	341.7625	337.2625	341.7625	336.0168	340.5168
44	HH	343.2625	347.7625	343.2625	347.7625	342.0171	346.5171
45	I I	349.2625	353.7625	349.2625	353.7625	348.0174	352.5174
46	JJ	355.2625	359.7625	355.2625	359.7625	354.0177	358.5177
47	KK	361.2625	365.7625	361.2625	365.7625	360.0180	364.5180
48	LL	367.2625	371.7625	367.2625	371.7625	366.0183	370.5183
49	MM	373.2625	377.7625	373.2625	377.7625	372.0186	376.5186
50	NN	379.2625	383.7625	379.2625	383.7625	378.0189	382.5189
51	OO	385.2625	389.7625	385.2625	389.7625	384.0192	388.5192
52	PP	391.2625	395.7625	391.2625	395.7625	390.0195	394.5195
53	QQ	397.2625	401.7625	397.2625	401.7625	396.0198	400.5198
54	RR	403.2500	407.7500	403.2625	407.7625	402.0201	406.5201
55	SS	409.2500	413.7500	409.2625	413.7625	408.0204	412.5204
56	TT	415.2500	419.7500	415.2625	419.7625	414.0207	418.5207
57	UU	421.2500	425.7500	421.2625	425.7625	420.0210	424.5210
58	VV	427.2500	431.7500	427.2625	431.7625	426.0213	430.5213
59	WW	433.2500	437.7500	433.2625	437.7625	432.0216	436.5216
60	XX	439.2500	443.7500	439.2625	443.7625	438.0219	442.5219
61	YY	445.2500	449.7500	445.2625	449.7625	444.0222	448.5222
62	ZZ	451.2500	455.7500	451.2625	455.7625	450.0225	454.5225
63	63	457.2500	461.7500	457.2625	461.7625	456.0228	460.5228
64	64	463.2500	467.7500	463.2625	467.7625	462.0231	466.5231
65	65	469.2500	473.7500	469.2625	473.7625	468.0234	472.5234
66	66	475.2500	479.7500	475.2625	479.7625	474.0237	478.5237
67	67	481.2500	485.7500	481.2625	485.7625	480.0240	484.5240
68	68	487.2500	491.7500	487.2625	491.7625	486.0243	490.5243
69	69	493.2500	497.7500	493.2625	497.7625	492.0246	496.5246
70	70	499.2500	503.7500	499.2625	503.7625	498.0249	502.5249
71	71	505.2500	509.7500	505.2625	509.7625	504.0252	508.5252
72	72	511.2500	515.7500	511.2625	515.7625	510.0255	514.5255
73	73	517.2500	521.7500	517.2625	521.7625	516.0258	520.5258
74	74	523.2500	527.7500	523.2625	527.7625	522.0261	526.5261
75	75	529.2500	533.7500	529.2625	533.7625	528.0264	532.5264
76	76	535.2500	539.7500	535.2625	539.7625	534.0267	538.5267
77	77	541.2500	545.7500	541.2625	545.7625	540.0270	544.5270
78	78	547.2500	551.7500	547.2625	551.7625	546.0273	550.5273
79	79	553.2500	557.7500	553.2625	557.7625	552.0276	556.5276
80	80	559.2500	563.7500	559.2625	563.7625	558.0279	562.5279
81	81	565.2500	569.7500	565.2625	569.7625	564.0282	568.5282

CATV channels

North America (cont'd)

EIA channel designation		Standard		Incremental		Harmonic	
new	old	Video	Audio	Video	Audio	Video	Audio
82	82	571.2500	575.7500	571.2625	575.7625	570.0285	574.5285
83	83	577.2500	581.7500	577.2625	581.7625	576.0288	580.5288
84	84	583.2500	587.7500	583.2625	587.7625	582.0291	586.5291
85	85	589.2500	593.7500	589.2625	593.7625	588.0294	592.5294
86	86	595.2500	599.7500	595.2625	599.7625	594.0297	598.5297
87	87	601.2500	605.7500	601.2625	605.7625	600.0300	604.5300
88	88	607.2500	611.7500	607.2625	611.7625	606.0303	610.5303
89	89	613.2500	617.7500	613.2625	617.7625	612.0306	616.5306
90	90	619.2500	623.7500	619.2625	623.7625	618.0309	622.5309
91	91	625.2500	629.7500	625.2625	629.7625	624.0312	628.5312
92	92	631.2500	635.7500	631.2625	635.7625	630.0315	634.5315
93	93	637.2500	641.7500	637.2625	641.7625	636.0318	640.5318
94	94	643.2500	647.7500	643.2625	647.7625	642.0321	646.5321
100	100	649.2500	653.7500	649.2625	653.7625	648.0324	652.5324
101	101	655.2500	659.7500	655.2625	659.7625	654.0327	658.5327
102	102	661.2500	665.7500	661.2625	665.7625	660.0330	664.5330
103	103	667.2500	671.7500	667.2625	671.7625	666.0333	670.5333
104	104	673.2500	677.7500	673.2625	677.7625	672.0336	676.5336
105	105	679.2500	683.7500	679.2625	683.7625	678.0339	682.5339
106	106	685.2500	689.7500	685.2625	689.7625	684.0342	688.5342
107	107	691.2500	695.7500	691.2625	695.7625	690.0345	694.5345
108	108	697.2500	701.7500	697.2625	701.7625	696.0348	700.5348
109	109	703.2500	707.7500	703.2625	707.7625	702.0351	706.5351
110	110	709.2500	713.7500	709.2625	713.7625	708.0354	712.5354
111	111	715.2500	719.7500	715.2625	719.7625	714.0357	718.5357
112	112	721.2500	725.7500	721.2625	725.7625	720.0360	724.5360
113	113	727.2500	731.7500	727.2625	731.7625	726.0363	730.5363
114	114	733.2500	737.7500	733.2625	737.7625	732.0366	736.5366
115	115	739.2500	743.7500	739.2625	743.7625	738.0369	742.5369
116	116	745.2500	749.7500	745.2625	749.7625	744.0372	748.5372
117	117	751.2500	755.7500	751.2625	755.7625	750.0375	754.5375
118	118	757.2500	761.7500	757.2625	761.7625	756.0378	760.5378
119	119	763.2500	767.7500	763.2625	767.7625	762.0381	766.5381
120	120	769.2500	773.7500	769.2625	773.7625	768.0384	772.5384
121	121	775.2500	779.7500	775.2625	779.7625	774.0387	778.5387
122	122	781.2500	785.7500	781.2625	785.7625	780.0390	784.5390
123	123	787.2500	791.7500	787.2625	791.7625	786.0393	790.5393
124	124	793.2500	797.7500	793.2625	797.7625	792.0396	796.5396
125	125	799.2500	803.7500	799.2625	803.7625	798.0399	802.5399
126	126	805.2500	809.7500	805.2625	809.7625	804.0402	808.5402
127	127	811.2500	815.7500	811.2625	815.7625	810.0405	814.5405
128	128	817.2500	821.7500	817.2625	821.7625	816.0408	820.5408
129	129	823.2500	827.7500	823.2625	827.7625	822.0411	826.5411
130	130	829.2500	833.7500	829.2625	833.7625	828.0414	832.5414
131	131	835.2500	839.7500	835.2625	839.7625	834.0417	838.5417
132	132	841.2500	845.7500	841.2625	845.7625	840.0420	844.5420
133	133	847.2500	851.7500	847.2625	851.7625	846.0423	850.5423

CATV channels

North America (cont'd)

EIA channel designation		Standard		Incremental		Harmonic	
new	old	Video	Audio	Video	Audio	Video	Audio
134	134	853.2500	857.7500	853.2625	857.7625	852.0426	856.5426
135	135	859.2500	863.7500	859.2625	863.7625	858.0429	862.5429
136	136	865.2500	869.7500	865.2625	869.7625	864.0432	868.5432
137	137	871.2500	875.7500	871.2625	875.7625	870.0435	874.5435
138	138	877.2500	881.7500	877.2625	881.7625	876.0438	880.5438
139	139	883.2500	887.7500	883.2625	887.7625	882.0441	886.5441
140	140	889.2500	893.7500	889.2625	893.7625	888.0444	892.5444
141	141	895.2500	899.7500	895.2625	899.7625	894.0447	898.5447
142	142	901.2500	905.7500	901.2625	905.7625	900.0450	904.5450
143	143	907.2500	911.7500	907.2625	911.7625	906.0453	910.5453
144	144	913.2500	917.7500	913.2625	917.7625	912.0456	916.5456
145	145	919.2500	923.7500	919.2625	923.7625	918.0459	922.5459
146	146	925.2500	929.7500	925.2625	929.7625	924.0462	928.5462
147	147	931.2500	935.7500	931.2625	935.7625	930.0465	934.5465
148	148	937.2500	941.7500	937.2625	941.7625	936.0468	940.5468
149	149	943.2500	947.7500	943.2625	947.7625	942.0471	946.5471
150	150	949.2500	953.7500	949.2625	953.7625	948.0474	952.5474
151	151	955.2500	959.7500	955.2625	959.7625	954.0477	958.5477
152	152	961.2500	965.7500	961.2625	965.7625	960.0480	964.5480
153	153	967.2500	971.7500	967.2625	971.7625	966.0483	970.5483
154	154	973.2500	977.7500	973.2625	977.7625	972.0486	976.5486
155	155	979.2500	983.7500	979.2625	983.7625	978.0489	982.5489
156	156	985.2500	989.7500	985.2625	989.7625	984.0492	988.5492
157	157	991.2500	995.7500	991.2625	995.7625	990.0495	994.5495
158	158	997.2500	1001.7500	997.2625	1001.7625	996.0498	1000.5498

NOTE:

The 'EIA' channel numbers are those recommended by a joint committee of the Electronics Industries Association and the National Cable Television Association (NCTA).

CATV channels

Japan
(NTSC; standard M)

Channel width: 6 MHz							
Ch. No.	**CATV**	**Video**	**Audio**	**Ch. No.**	**CATV**	**Video**	**Audio**
1	1	91.25	95.75	C37	37	307.25	311.75
2	2	97.25	101.75	C38	38	313.25	317.75
3	3	103.25	107.75	C39	39	319.25	323.75
4	4	171.25	175.75	C40	40	325.25	329.75
5	5	177.25	181.75	C41	41	331.25	335.75
6	6	183.25	187.75	C42	42	337.25	341.75
7	7	189.25	193.75	C43	43	343.25	347.75
8	8	193.25	197.75	C44	44	349.25	353.75
9	9	199.25	203.75	C45	45	355.25	359.75
10	10	205.25	209.75	C46	46	361.25	365.75
11	11	211.25	215.75	C47	47	367.25	371.75
12	12	217.25	221.75	C48	48	373.25	377.75
C13	13	109.25	113.75	C49	49	379.25	383.75
C14	14	115.25	119.75	C50	50	385.25	389.75
C15	15	121.25	125.75	C51	51	391.25	395.75
C16	16	127.25	131.75	C52	52	397.25	401.75
C17	17	133.25	137.75	C53	53	403.25	407.75
C18	18	139.25	143.75	C54	54	409.25	413.75
C19	19	145.25	149.75	C55	55	415.25	419.75
C20	20	151.25	155.75	C56	56	421.25	425.75
C21	21	157.25	161.75	C57	57	427.25	431.75
C22	22	165.25	169.75	C58	58	433.25	437.75
C23	23	223.25	227.75	C59	59	439.25	443.75
C24	24	231.25	235.75	C60	60	445.25	449.75
C25	25	237.25	241.75	C61	61	451.25	455.75
C26	26	243.25	247.75	C62	62	457.25	461.75
C27	27	249.25	253.75	C63	63	463.25	467.75
C28	28	253.25	257.75	U13	64	471.25	475.75
C29	29	259.25	263.75	U14	65	477.25	481.75
C30	30	265.25	269.75	U15	66	483.25	487.75
C31	31	271.25	275.75	U16	67	489.25	493.75
C32	32	277.25	281.75	U17	68	495.25	499.75
C33	33	283.25	287.75	U18	69	501.25	505.75
C34	34	289.25	293.75	U19	70	507.25	511.75
C35	35	295.25	299.75	U20	71	513.25	517.75
C36	36	301.25	305.75	U21	72	519.25	523.75

NOTE:
The Chrominance subcarrier is located 3.57561149 MHz above the video carrier.

CATV channels

Japan (cont'd)

Channel width: 6 MHz							
Ch. No.	**CATV**	**Video**	**Audio**	**Ch. No.**	**CATV**	**Video**	**Audio**
U22	73	525.25	529.75	U43	94	651.25	655.75
U23	74	531.25	535.75	U44	95	657.25	661.75
U24	75	537.25	541.75	U45	96	663.25	667.75
U25	76	543.25	547.75	U46	97	669.25	673.75
U26	77	549.25	553.75	U47	98	675.25	679.75
U27	78	555.25	559.75	U48	99	681.25	685.75
U28	79	561.25	565.75	U49	100	687.25	691.75
U29	80	567.25	571.75	U50	101	693.25	697.75
U30	81	573.25	577.75	U51	102	699.25	703.75
U31	82	579.25	583.75	U52	103	705.25	709.75
U32	83	585.25	589.75	U53	104	711.25	715.75
U33	84	591.25	595.75	U54	105	717.25	721.75
U34	85	597.25	601.75	U55	106	723.25	727.75
U35	86	603.25	607.75	U56	107	729.25	733.75
U36	87	609.25	613.75	U57	108	735.25	739.75
U37	88	615.25	619.75	U58	109	741.25	745.75
U38	89	621.25	625.75	U59	110	747.25	751.75
U39	90	627.25	631.75	U60	111	753.25	757.75
U40	91	633.25	637.75	U61	112	759.25	763.75
U41	92	639.25	643.75	U62	113	765.25	769.75
U42	93	645.25	649.75				

CATV channels

People's Republic of China (PAL; standard D/K)

Channel width: 8 MHz					
Ch. No.	**Video**	**Audio**	**Ch. No.**	**Video**	**Audio**
Z1	112.25	118.75	DS16	495.25	501.75
Z2	120.25	126.75	DS17	503.25	509.75
Z3	128.25	134.75	DS18	511.25	517.75
Z4	136.25	142.75	DS19	519.25	525.75
Z5	144.25	150.75	DS20	527.25	533.75
Z6	152.25	158.75	DS21	535.25	541.75
Z7	160.25	166.75	DS22	543.25	549.75
DS6	168.25	174.75	DS23	551.25	557.75
DS7	176.25	182.75	DS24	559.25	565.75
DS8	184.25	190.75	Z38	567.25	573.75
DS9	192.25	198.75	Z39	575.25	581.75
DS10	200.25	206.75	Z40	583.25	589.75
DS11	208.25	214.75	Z41	591.25	597.75
DS12	216.25	222.75	Z42	599.25	605.75
Z8	224.25	230.75	DS25	607.25	613.75
Z9	232.25	238.75	DS26	615.25	621.75
Z10	240.25	246.75	DS27	623.25	629.75
Z11	248.25	254.75	DS28	631.25	637.75
Z12	256.25	262.75	DS29	639.25	645.75
Z13	264.25	270.75	DS30	647.25	653.75
Z14	272.25	278.75	DS31	655.25	661.75
Z15	280.25	286.75	DS32	663.25	669.75
Z16	288.25	294.75	DS33	671.25	677.75
Z17	296.25	302.75	DS34	679.25	685.75
Z18	304.25	310.75	DS35	687.25	693.75
Z19	312.25	318.75	DS36	695.25	701.75
Z20	320.25	326.75	DS37	703.25	709.75
Z21	328.25	334.75	DS38	711.25	717.75
Z22	336.25	342.75	DS39	719.25	725.75
Z23	344.25	350.75	DS40	727.25	733.75
Z24	352.25	358.75	DS41	735.25	741.75
Z25	360.25	366.75	DS42	743.25	749.75
Z26	368.25	374.75	DS43	751.25	757.75
Z27	376.25	382.75	DS44	759.25	765.75
Z28	384.25	390.75	DS45	767.25	773.75
Z29	392.25	398.75	DS46	775.25	781.75
Z30	400.25	406.75	DS47	783.25	789.75
Z31	408.25	414.75	DS48	791.25	797.75
Z32	416.25	422.75	DS49	799.25	805.75
Z33	424.25	430.75	DS50	807.25	813.75
Z34	432.25	438.75	DS51	815.25	821.75
Z35	440.25	446.75	DS52	823.25	829.75
Z36	448.25	454.75	DS53	831.25	837.75
Z37	456.25	462.75	DS54	839.25	845.75
DS13	471.25	477.75	DS55	847.25	853.75
DS14	479.25	485.75	DS56	855.25	861.75
DS15	487.25	493.75			

CATV channels

Europe
(PAL; standard B/G)

Channel width: 7 and 8 MHz					
Ch. No.	**Video**	**Audio**	**Ch. No.**	**Video**	**Audio**
↓ 7 MHz channel spacing ↓			↓ 8 MHz channel spacing ↓		
E2	48.25	53.75	S21	303.25	308.75
E3	55.25	60.75	S22	311.25	316.75
E4	62.25	67.75	S23	319.25	324.75
			S24	327.25	332.75
S2	112.25	117.75	S25	335.25	340.75
S3	119.25	124.75	S26	343.25	348.75
S4	126.25	131.75	S27	351.25	356.75
S5	133.25	138.75	S28	359.25	364.75
S6	140.25	145.75	S29	367.25	372.75
S7	147.25	152.75	S30	375.25	380.75
S8	154.25	159.75	S31	383.25	388.75
S9	161.25	166.75	S32	391.25	396.75
S10	168.25	173.75	S33	399.25	404.75
			S34	407.25	412.75
E5	175.25	180.75	S35	415.25	420.75
E6	182.25	187.75	S36	423.25	428.75
E7	189.25	194.75	S37	431.25	436.75
E8	196.25	201.75	S38	439.25	444.75
E9	203.25	208.75	S39	447.25	452.75
E10	210.25	215.75	S40	455.25	460.75
E11	217.25	222.75	S41	463.25	468.75
E12	224.25	229.75			
			E21	471.25	476.75
S11	231.25	236.75	E22	479.25	484.75
S12	238.25	243.75	E23	487.25	492.75
S13	245.25	250.75	E24	495.25	500.75
S14	252.25	257.75	E25	503.25	508.75
S15	259.25	264.75	E26	511.25	516.75
S16	266.25	271.75	E27	519.25	524.75
S17	273.25	278.75	E28	527.25	532.75
S18	280.25	285.75	E29	535.25	540.75
S19	287.25	292.75	E30	543.25	548.75
S20	294.25	299.75	E31	551.25	556.75
			E32	559.25	564.75
			E33	567.25	572.75
			E34	575.25	580.75
			E35	583.25	588.75

NOTE:
The channels E2 through E69 are designated K2 through K69 in Germany.

CATV channels **Europe (cont'd)**

Ch. No.	Video	Audio	Ch. No.	Video	Audio
↓ 8 MHz channel spacing ↓			↓ 8 MHz channel spacing ↓		
E36	591.25	596.75	E53	727.25	732.75
E37	599.25	604.75	E54	735.25	740.75
E38	607.25	612.75	E55	743.25	748.75
E39	615.25	620.75	E56	751.25	756.75
E40	623.25	628.75	E67	759.25	764.75
E41	631.25	636.75	E58	767.25	772.75
E42	639.25	644.75	E59	775.25	780.75
E43	647.25	652.75	E60	783.25	788.75
E44	655.25	660.75	E61	791.25	796.75
E45	663.25	668.75	E62	799.25	804.75
E46	671.25	676.75	E63	807.25	812.75
E47	679.25	684.75	E64	815.25	820.75
E48	687.25	692.75	E65	823.25	828.75
E49	695.25	700.75	E66	831.25	836.75
E50	703.25	708.75	E67	839.25	844.75
E51	711.25	716.75	E68	847.25	852.75
E52	719.25	724.75	E69	855.25	860.75

NOTE:
The channels E2 through E69 are designated K2 through K69 in Germany.

CATV channels

United Kingdom
(PAL; ITU-R* standard I)

Channel width: 8 MHz					
Video	**Audio**	**Video**	**Audio**	**Video**	**Audio**
8.0	14.0	296.0	302.0	584.0	590.0
16.0	22.0	304.0	310.0	592.0	598.0
24.0	30.0	312.0	318.0	600.0	606.0
32.0	38.0	320.0	326.0	608.0	614.0
40.0	46.0	328.0	334.0	616.0	622.0
48.0	54.0	336.0	342.0	624.0	630.0
56.0	62.0	344.0	350.0	632.0	638.0
64.0	70.0	352.0	358.0	640.0	646.0
72.0	78.0	360.0	366.0	648.0	654.0
80.0	86.0	368.0	374.0	656.0	662.0
88.0	94.0	376.0	382.0	664.0	670.0
96.0	102.0	384.0	390.0	672.0	678.0
104.0	110.0	392.0	398.0	680.0	686.0
112.0	118.0	400.0	406.0	688.0	694.0
120.0	126.0	408.0	414.0	696.0	702.0
128.0	134.0	416.0	422.0	704.0	710.0
136.0	142.0	424.0	430.0	712.0	718.0
144.0	150.0	432.0	438.0	720.0	726.0
152.0	158.0	440.0	446.0	728.0	734.0
160.0	166.0	448.0	454.0	736.0	742.0
168.0	174.0	456.0	462.0	744.0	750.0
176.0	182.0	464.0	470.0	752.0	758.0
184.0	190.0	472.0	478.0	760.0	766.0
192.0	198.0	480.0	486.0	768.0	774.0
200.0	206.0	488.0	494.0	776.0	782.0
208.0	214.0	496.0	502.0	784.0	790.0
216.0	222.0	504.0	510.0	792.0	798.0
224.0	230.0	512.0	518.0	800.0	806.0
232.0	238.0	520.0	526.0	808.0	814.0
240.0	246.0	528.0	534.0	816.0	822.0
248.0	254.0	536.0	542.0	824.0	830.0
256.0	262.0	544.0	550.0	832.0	838.0
264.0	270.0	552.0	558.0	840.0	846.0
272.0	278.0	560.0	566.0	848.0	854.0
280.0	286.0	568.0	574.0	856.0	862.0
288.0	294.0	576.0	582.0	864.0	870.0

Off-air channels

North America
(ITU-R standard M; NTSC)

CHAN	BW (MHz)	VIDEO	CHROMA	AUDIO
Lo VHF				
2	54-60	55.25	58.83	59.75
3	60-66	61.25	64.83	65.75
4	66-72	67.25	70.83	71.75
5	76-82	77.25	80.83	81.75
6	82-88	83.25	86.83	87.75
Hi VHF				
7	174-180	175.25	178.83	179.75
8	180-186	181.25	184.83	185.75
9	186-192	187.25	190.83	191.75
10	192-198	193.25	196.83	197.75
11	198-204	199.25	202.83	203.75
12	204-210	205.25	208.83	209.75
13	210-216	211.25	214.83	215.75
UHF				
14	470-476	471.25	474.83	475.75
15	476-482	477.25	480.83	481.75
16	482-488	483.25	486.83	487.75
17	488-494	489.25	492.83	493.75
18	494-500	495.25	498.83	499.75
19	500-506	501.25	504.83	505.75
20	506-512	507.25	510.83	511.75
21	512-518	513.25	516.83	517.75
22	518-524	519.25	522.83	523.75
23	524-530	525.25	528.83	529.75
24	530-536	531.25	534.83	535.75
25	536-542	537.25	540.83	541.75
26	542-548	543.25	546.83	547.75
27	548-554	549.25	552.83	553.75
28	554-560	555.25	558.83	559.75
29	560-566	561.25	564.83	565.75
30	566-572	567.25	570.83	571.75
31	572-578	573.25	576.83	577.75
32	578-584	579.25	582.83	583.75
33	584-590	585.25	588.83	589.75
34	590-596	591.25	594.83	595.75
35	596-602	597.25	600.83	601.75
36	602-608	603.25	606.83	607.75
37	608-614	609.25	612.83	613.75
38	614-620	615.25	618.83	619.75

CHAN	BW (MHz)	VIDEO	CHROMA	AUDIO
UHF				
39	620-626	621.25	624.83	625.75
40	626-632	627.25	630.83	631.75
41	632-638	633.25	636.83	637.75
42	638-644	639.25	642.83	643.75
43	644-650	645.25	648.83	649.75
44	650-656	651.25	654.83	655.75
45	656-662	657.25	660.83	661.75
46	662-668	663.25	666.83	667.75
47	668-674	669.25	672.83	673.75
48	674-680	675.25	678.83	679.75
49	680-686	681.25	684.83	685.75
50	686-692	687.25	690.83	691.75
51	692-698	693.25	696.83	697.75
52	698-704	699.25	702.83	703.75
53	704-710	705.25	708.83	709.75
54	710-716	711.25	714.83	715.75
55	716-722	717.25	720.83	721.75
56	722-728	723.25	726.83	727.75
57	728-734	729.25	732.83	733.75
58	734-740	735.25	738.83	739.75
59	740-746	741.25	744.83	745.75
60	746-752	747.25	750.83	751.75
61	752-758	753.25	756.83	757.75
62	758-764	759.25	762.83	763.75
63	764-770	765.25	768.83	769.75
64	770-776	771.25	774.83	775.75
65	776-782	777.25	780.83	781.75
66	782-788	783.25	786.83	787.75
67	788-794	789.25	792.83	793.75
68	794-800	795.25	798.83	799.75
69	800-806	801.25	804.83	805.75
70	806-812	807.25	810.83	811.75
71	812-818	813.25	816.83	817.75
72	818-824	819.25	822.83	823.75
73	824-830	825.25	828.83	829.75
74	830-836	831.25	834.83	835.75
75	836-842	837.25	840.83	841.75
76	842-848	843.25	846.83	847.75
77	848-854	849.25	852.83	853.75
78	854-860	855.25	858.83	859.75
79	860-866	861.25	864.83	865.75
80	866-872	867.25	870.83	871.75
81	872-878	873.25	876.83	877.75
82	878-884	879.25	882.83	883.75
83	884-890	885.25	888.83	889.75

VHF off-air channels
ITU-R standards B,D,I & L

Channel	BW (MHz)	Video	Audio
Europe (standard B); 7 MHz spacing			
E2	47 – 54	48.25	53.75
E3	54 – 61	55.25	60.75
E4	61 – 68	62.25	67.75
S2	111-118	112.25	117.75
S3	118-125	119.25	124.75
S4	125-132	126.25	131.75
S5	132-139	133.25	138.75
S6	139-146	140.25	145.75
S7	146-153	147.25	152.75
S8	153-160	154.25	159.75
S9	160-167	161.25	166.75
S10	167-174	168.25	173.75
E5	174-181	175.25	180.75
E6	181-188	182.25	187.75
E7	188-195	189.25	194.75
E8	195-202	196.25	201.75
E9	202-209	203.25	208.75
E10	209-216	210.25	215.75
E11	216-223	217.25	222.75
E12	223-230	224.25	229.75
S11	230-237	231.25	236.75
S12	237-244	238.25	243.75
S13	244-251	245.25	250.75
S14	251-258	252.25	257.75
S15	258-265	259.25	264.75
S16	265-272	266.25	271.75
S17	272-279	273.25	278.75
S18	279-286	280.25	285.75
S19	286-293	287.25	292.75
S20	293-300	294.25	299.75

Australia (standard B); 7 MHz spacing			
0	45 – 52	46.25	51.75
1	56 – 63	57.25	62.75
2	63 – 70	64.25	69.75
3	85 – 92	86.25	91.75
4	94–101	95.25	100.75
5	101-108	102.25	107.75
5A	137-144	138.25	143.75
6	174-181	175.25	180.75
7	181-188	182.25	187.75
8	188-195	189.25	194.75
9	195-202	196.25	201.75
10	208-215	209.25	214.75
11	215-222	216.25	221.75

Channel	BW (MHz)	Video	Audio
Italy (standard B); 7 MHz spacing			
A	52.5-59.5	53.75	59.25
B	61 – 68	62.25	67.75
C	81 – 88	82.25	87.75
D	174-181	175.25	180.75
E	182.5-189.5	183.75	189.75
F	191-198	192.25	197.75
G	200-207	201.25	206.75
H	209-216	210.25	215.75
H_1	216-223	217.25	222.75
H_2	223-230	224.25	229.75

Morocco (standard B); 7 MHz spacing			
M 4	162-169	163.25	168.75
M 5	170-177	171.25	176.75
M 6	178-185	179.25	184.75
M 7	186-193	187.25	192.75
M 8	194-201	195.25	200.75
M 9	202-209	203.25	208.75
M 10	210-217	211.25	216.75

New Zealand (standard B); 7 MHz spacing			
1	44 – 51	45.25	50.75
2	54 – 61	55.25	60.75
3	61 – 68	62.25	67.75
4	174-181	175.25	180.75
5	181-188	182.25	187.75
6	188-195	189.25	194.75
7	195-202	196.25	201.75
8	202-209	203.25	208.75
9	209-216	210.25	215.75
10	216-223	217.25	222.75

People's Rep. of China (standard D); 8 MHz spacing			
1	48.5-56.5	49.75	56.25
2	56.5-64.5	57.75	64.25
3	64.5-72.5	65.75	72.25
4	76.0-84.0	77.25	83.75
5	84.0-92.0	85.25	91.75
6	167-175	168.25	174.75
7	175-183	176.25	182.75
8	183-191	184.25	190.75
9	191-199	192.25	198.75
10	199-207	200.25	206.75
11	207-215	208.25	214.75
12	215-223	216.25	222.75

VHF off-air channels
ITU-R standards B,D,I & L

Channel	BW (MHz)	Video	Audio
OIRT* (standard D); 8 MHz spacing			
R I	48.5-56.5	49.75	56.25
R II	58 – 66	59.25	65.75
R III	76 – 84	77.25	83.75
R IV	84 – 92	85.25	91.75
R V	92 – 100	93.25	99.75
R VI	174-182	175.25	181.75
R VII	182-190	183.25	189.75
R VIII	190-198	191.25	197.75
R IX	198-206	199.25	205.75
R X	206-214	207.25	213.75
R XI	214-222	215.25	221.75
R XII	222-230	223.25	229.75

Ireland (standard I); 8 MHz spacing			
I A	44.5-52.5	45.75	51.75
I B	52.5-60.5	53.75	59.75
I C	60.5-68.5	61.75	67.75
I D	174-182	175.25	181.25
I E	182-190	183.25	189.25
I F	190-198	191.25	197.25
I G	198-206	199.25	205.25
I H	206-214	207.25	213.25
I J	214-222	215.25	221.25

South Africa (standard I); 8 MHz spacing			
4	174-182	175.25	181.25
5	182-190	183.25	189.25
6	190-198	191.25	197.25
7	198-206	199.25	205.25
8	206-214	207.25	213.25
9	214-222	215.25	221.25
10	222-230	223.25	229.25
11	230-238	231.25	237.25
(12)	238-246	not defined	
13	246-254	247.25	253.25

*** OIRT: Organisation Internationale de Radiodiffusion-Télévision.**
This organisation represented the broadcasters of Eastern European countries. In 1993 it was incorporated into the European Broadcasting Union (EBU).

Channel	BW (MHz)	Video	Audio
France (standard L); 8 MHz spacing			
A	41 – 49	47.75	41.25
B	49 – 57	55.75	49.25
C	57 – 65	63.75	57.25
C 1	53.75-61.75	60.50	54.0
1	174.75-182.75	176.0	182.50
2	182.75-190.75	184.0	190.50
3	190.75-198.75	192.0	198.50
4	198.75-206.75	200.0	206.50
5	206.75-214.75	208.0	214.50
6	214.75-222.75	216.0	222.50

Japan (standard M); 6 MHz spacing			
J 1	90 – 96	91.25	95.75
J 2	96 – 102	97.25	101.75
J 3	102-108	103.25	107.75
J 4	170-176	171.25	175.75
J 5	176-182	177.25	181.75
J 6	182-188	183.25	187.75
J 7*	188-194	189.25	193.75
J 8*	192-198	193.25	197.75
J 9	198-204	199.25	203.75
J 10	204-210	205.25	209.75
J 11	210-216	211.25	215.75
J 12	216-222	217.25	221.75

* Channel spacing is 4 MHz

UHF off-air channels
ITU-R standards G,H,I,K & L

CHANNEL		BW (MHz)	VIDEO	AUDIO		
Europe	P.R. China			G,H	I	K,L
UHF band IV						
21	13	470-478	471.25	476.75	477.25	477.75
22	14	478-486	479.25	484.75	485.25	485.75
23	15	486-494	487.25	492.75	493.25	493.75
24	16	494-502	495.25	500.75	501.25	501.75
25	17	502-510	503.25	508.75	509.25	509.75
26	18	510-518	511.25	516.75	517.25	517.75
27	19	518-526	519.25	524.75	525.25	525.75
28	20	526-534	527.25	532.75	533.25	533.75
29	21	534-542	535.25	540.75	541.25	541.75
30	22	542-550	543.25	548.75	549.25	549.75
31	23	550-558	551.25	556.75	557.25	557.75
32	24	558-566	559.25	564.75	565.25	565.75
33	↑	566-574	567.25	572.75	573.25	573.75
34		574-582	575.25	580.75	581.25	581.75
35	Not defined	582-590	583.25	588.75	589.25	589.75
36		590-598	591.25	596.75	597.25	597.75
37	↓	598-606	599.25	604.75	605.25	605.75
UHF band V						
38	25	606-614	607.25	612.75	613.25	613.75
39	26	614-622	615.25	620.75	621.25	621.75
40	27	622-630	623.25	628.75	629.25	629.75
41	28	630-638	631.25	636.75	637.25	637.75
42	29	638-646	639.25	644.75	645.25	645.75
43	30	646-654	647.25	652.75	653.25	653.75
44	31	654-662	655.25	660.75	661.25	661.75
45	32	662-670	663.25	668.75	669.25	669.75
46	33	670-678	671.25	676.75	677.25	677.75
47	34	678-686	679.25	684.75	685.25	685.75
48	35	686-694	687.25	692.75	693.25	693.75
49	36	694-702	695.25	700.75	701.25	701.75
50	37	702-710	703.25	708.75	709.25	709.75
51	38	710-718	711.25	716.75	717.25	717.75
52	39	718-726	719.25	724.75	725.25	725.75
53	40	726-734	727.25	732.75	733.25	733.75
54	41	734-742	735.25	740.75	741.25	741.75
55	42	742-750	743.25	748.75	749.25	749.75
56	43	750-758	751.25	756.75	757.25	757.75
57	44	758-766	759.25	764.75	765.25	765.75
58	45	766-774	767.25	772.75	773.25	773.75
59	46	774-782	775.25	780.75	781.25	781.75
60	47	782-790	783.25	788.75	789.25	789.75
61	48	790-798	791.25	796.75	797.25	797.75
62	49	798-806	799.25	804.75	805.25	805.75
63	50	806-814	807.25	812.75	813.25	813.75

UHF off-air channels
ITU-R standards G,H,I,K & L (cont'd)

CHANNEL		BW (MHz)	VIDEO	AUDIO		
Europe	P.R. China			G,H	I	K,L
UHF band V						
64	51	814-822	815.25	820.75	821.25	821.75
65	52	822-830	823.25	828.75	829.25	829.75
66	53	830-838	831.25	836.75	837.25	837.75
67	54	838-846	839.25	844.75	845.25	845.75
68	55	846-854	847.25	852.75	853.25	853.75
69	56	854-862	855.25	860.75	861.25	861.75
↑	57	862-870	863.25			869.75
	58	870-878	871.25			877.75
Not defined	59	878-886	879.25			885.75
	60	886-894	887.25			893.75
	61	894-902	895.25			901.75
↓	62	902-910	903.25			909.75

ITU-R standard B

CHAN	BW (MHz)	VIDEO	CHROMA	AUDIO
UHF band IV				
28	526-533	527.25	531.68	532.75
29	533-540	534.25	538.68	539.75
30	540-547	541.25	545.68	546.75
31	547-554	548.25	552.68	553.75
32	554-561	555.25	559.68	560.75
33	561-568	562.25	566.68	567.75
34	568-575	569.25	573.68	574.75
35	575-582	576.25	580.68	581.75
UHF band V				
36	582-589	583.25	587.68	588.75
37	589-596	590.25	594.68	595.75
38	596-603	597.25	601.68	602.75
------- Other channels with 7 MHz spacing -------				
67	799-806	800.25	804.68	805.75
68	806-813	807.25	811.68	812.75
69	813-820	814.25	818.68	819.75

Refer to Section 3 for more information on the RF structure of the TV signal in each Standard.

RF CHARACTERISTICS OF TV SIGNALS

General

There are many different TV standards in use around the world, defining in detail the baseband and RF structure of the signal, but for the broadband engineer and technician the key parameters are the bandwidth, the dimensions of the lower (vestigial) and upper sidebands, and the frequency and amplitude relationships of the vision (luminance), color (chrominance) and audio subcarriers.

In terms of these parameters, the vast majority of TV transmissions fall into just six categories, which are illustrated in the following diagrams.

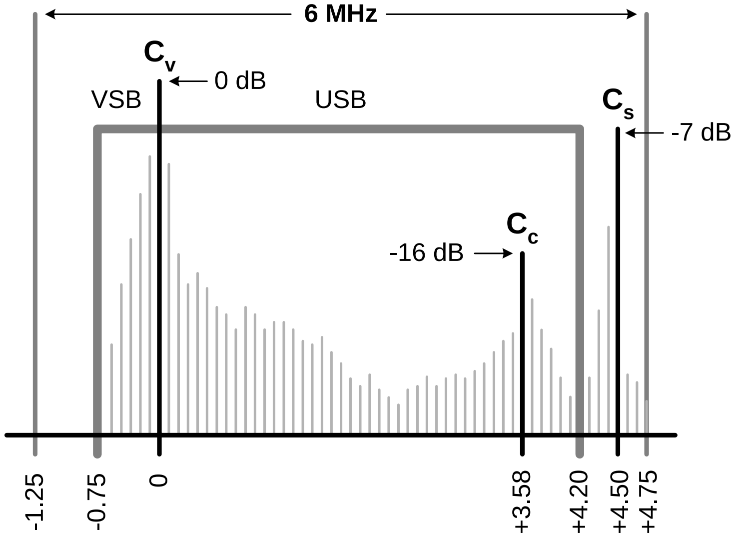
Note that these diagrams do not define such parameters as field frequency, line frequency, or color encoding technique, which distinguish the NTSC, PAL and SECAM systems.

The letters B, G, M, etc. are referred to as TV standards, and the encoding techniques (NTSC, PAL, etc.) are referred to as systems.

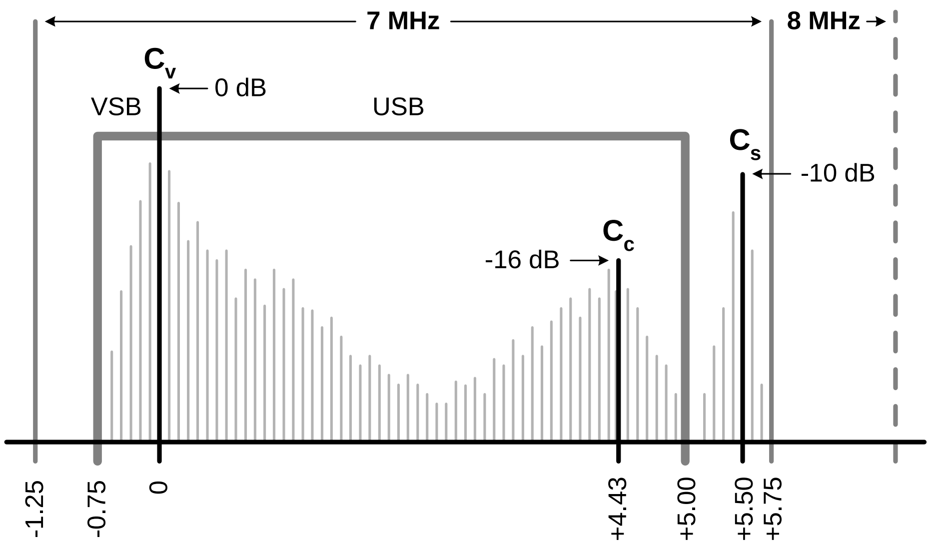
Standard:	**can be used with these Systems:**
B	PAL, SECAM
D	SECAM
G	PAL, SECAM
H	PAL, SECAM
I	PAL
K	SECAM
K1	SECAM
L	SECAM
M	NTSC, PAL
N	PAL

NTSC: National Television Standards Committee (U.S.A.)
PAL: Phase Alternating Line
SECAM: Séquentielle à mémoire

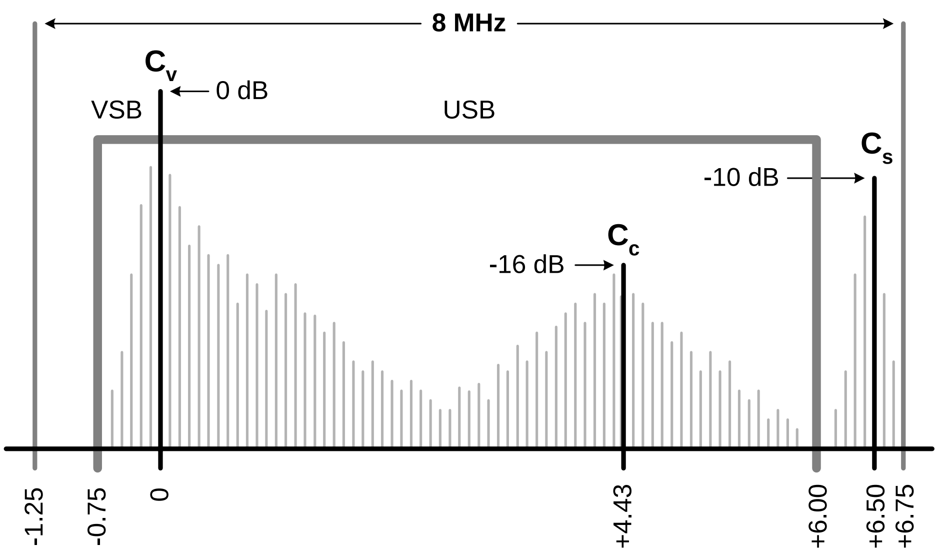
M, N



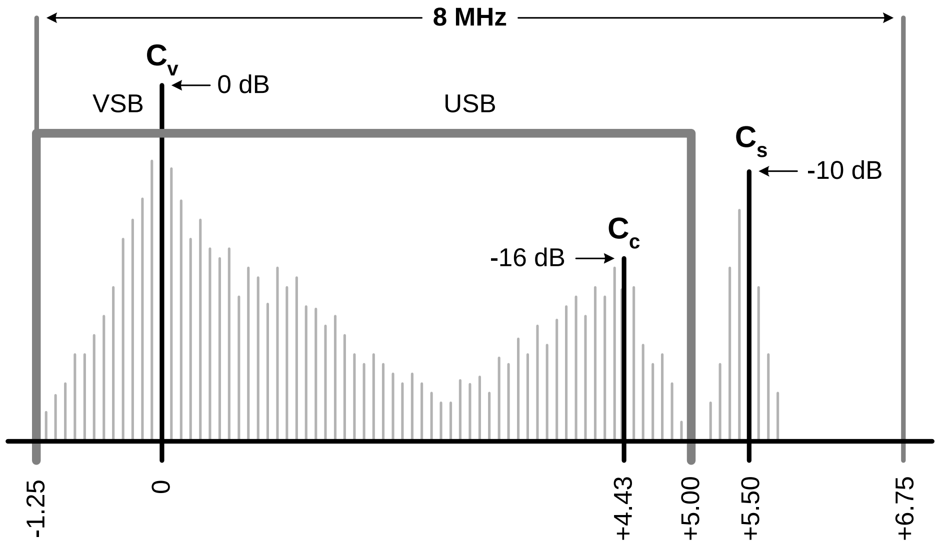
B (7 MHz)
G (8 MHz)



D, K

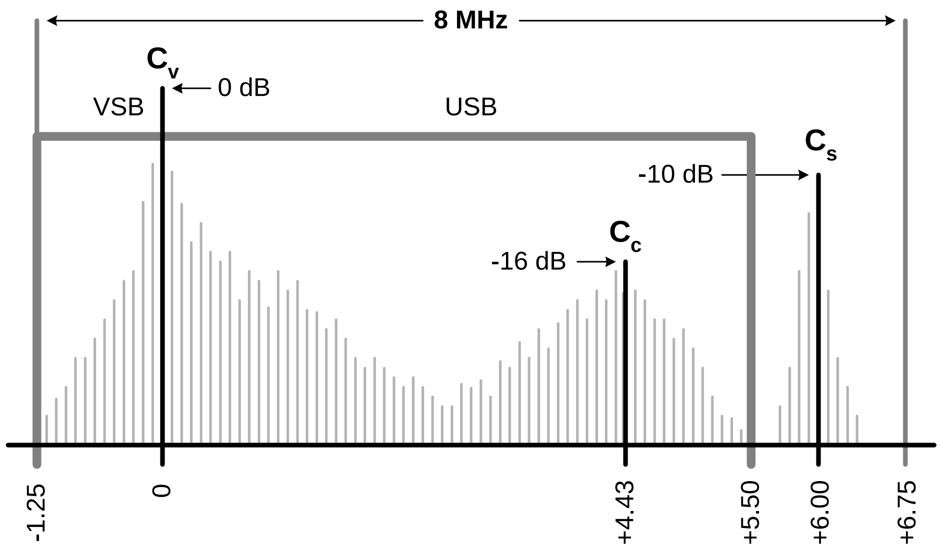


H



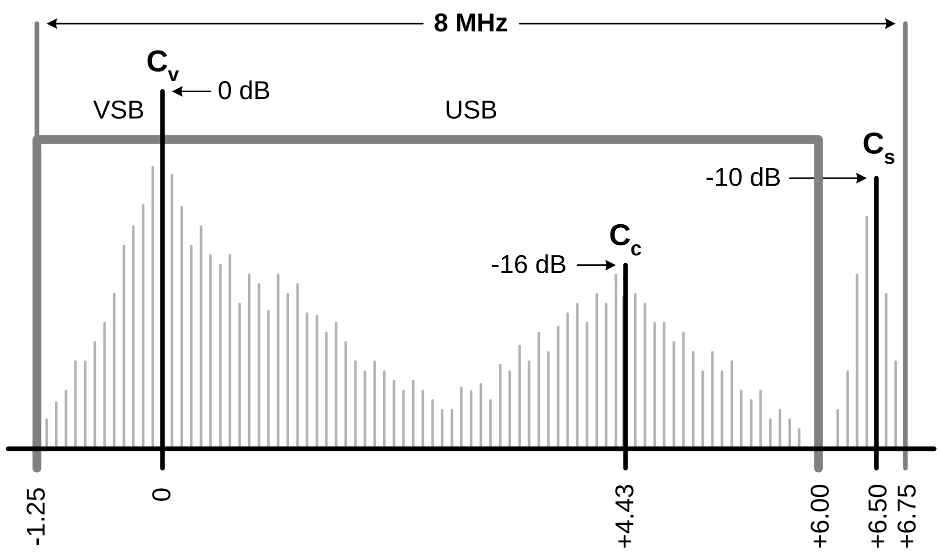
8 MHz
Cv
0 dB
VSB
USB
Cs
-10 dB
Cc
-16 dB
-1.25
0
+4.43
+5.00
+5.50
+6.75

I



8 MHz
Cv
0 dB
VSB
USB
Cs
-10 dB
Cc
-16 dB
-1.25
0
+4.43
+5.50
+6.00
+6.75

K1, L



8 MHz
Cv
0 dB
VSB
USB
Cs
-10 dB
Cc
-16 dB
-1.25
0
+4.43
+6.00
+6.50
+6.75

Systems and Standards by Country

Country	System	Std.		Country	System	Std.
Afghanistan	PAL	D		El Salvador	NTSC	M
Albania	PAL	B/G		Equatorial Guinea	PAL	B
Algeria	PAL	B		Estonia	PAL	B/G
Argentina	PAL	N		Ethiopia	PAL	B
Angola	PAL	I		Finland	PAL	B/G
Australia	PAL	B		France	SECAM	L
Antigua & Barbuda	NTSC	M		French Guiana	SECAM	K
Austria	PAL	B/G		Gabon	SECAM	K
Azores (Portugal)	PAL	B		Germany	PAL	B/G
Bahamas	NTSC	M		Ghana	PAL	B
Bahrain	PAL	B		Gibraltar	PAL	B
Bangladesh	PAL	B		Greece	SECAM	B/G
Barbados	NTSC	M		Greenland	NTSC	M
Belgium	PAL	B/G		Granada	NTSC	M
Belize	NTSC	M		Guadeloup	SECAM	K
Bermuda	NTSC	M		Guam	NTSC	M
Bolivia	NTSC	N		Guatemala	NTSC	M
Brazil	PAL	M		Haiti	SECAM	M
Bosnia	PAL	B/H		Honduras	NTSC	M
Brunei	PAL	B		Hong Kong	PAL	I
Bulgaria	SECAM	D		Hungary	PAL	B/G
Burma (Myanmar)	NTSC	N		Iceland	PAL	B
Cambodia	SECAM	M		India	PAL	B
Cameroon	PAL	B		Indonesia	PAL	B
Canada	NTSC	M		Iran	SECAM	B
Canary Islands	PAL	B		Iraq	SECAM	B
Central African Rep.	SECAM	K		Ireland (Republic of)	PAL	I
Chad	SECAM	K		Israel	PAL	B/G
Chile	NTSC	M		Italy	PAL	B/G
China	PAL	D		Ivory Coast	SECAM	K
Colombia	NTSC	M		Jamaica	NTSC	M
Congo	SECAM	D		Japan	NTSC	M
Costa Rica	NTSC	M		Jordan	PAL	B
Cuba	NTSC	M		Kenya	PAL	B
Cyprus	PAL	B/G		Korea (P.D.R.)	PAL	D
Czech Republic	SECAM	D/K		Korea (South)	NTSC	M
Denmark	PAL	B/G		Kuwait	PAL	B/G
Dominican Rep.	NTSC	M		Laos	PAL	M
Ecuador	NTSC	M		Latvia	PAL	B/G
Egypt	SECAM	B		Lebanon	PAL	B/G
Eire (Ireland)	PAL	I		Liberia	PAL	B

Country	System	Std.		Country	System	Std.
Libya	PAL	B		Sierra Leone	PAL	B
Lithuania	PAL	B/G		Singapore	PAL	B
Luxembourg	PAL	B/G		Slovakia	SECAM	D/K
Malaysia	PAL	B		Slovenia	PAL	B/G
Mali	SECAM	K		Somalia	PAL	B
Malta	PAL	B/G		South Africa	PAL	I
Martinique	SECAM	K		Spain	PAL	B/G
Mauritius	SECAM	B		Sri Lanka	PAL	B
Mexico	NTSC	M		Sudan	PAL	B
Monaco	SECAM	L/G		Surinam	NTSC	M
Mongolia	SECAM	D		Swaziland	PAL	B/G
Montenegro	PAL	B/H		Sweden	PAL	B/G
Morocco	SECAM	B		Switzerland	PAL	B/G
Mozambique	PAL	G		Syria	SECAM	B
Nepal	PAL	B		Tahiti	SECAM	K
Netherlands	PAL	B/G		Taiwan	NTSC	M
New Zealand	PAL	B/G		Tanzania	PAL	I
Nicaragua	NTSC	M		Thailand	PAL	B
Niger	SECAM	K		Tonga	NTSC	M
Nigeria	PAL	B		Trinidad y Tobago	NTSC	M
Norway	PAL	B/G		Tunisia	SECAM	B
Oman	PAL	B/G		Turkey	PAL	B
Pakistan	PAL	B		Uganda	PAL	B
Panama	NTSC	M		Ukraine	SECAM	D
Paraguay	PAL	N		U. A. Emirates	PAL	B/G
Peru	NTSC	M		United Kingdom	PAL	I
Philippines	NTSC	M		U.S.A.	NTSC	M
Poland	PAL	D/K		Uruguay	PAL	N
Portugal	PAL	B/G		Uzbekistan	SECAM	D
Puerto Rico	NTSC	M		Venezuela	NTSC	M
Qatar	PAL	B		Vietnam	PAL	M
Reunion	SECAM	K		Virgin Islands (U.S.)	NTSC	M
Romania	PAL	G		Yemen (A.R.)	PAL	B
Russian Federation	SECAM	D		Yemen (P.D.R.)	PAL	B
Rwanda	SECAM	K		Yugoslavia	PAL	B/H
St Kitts & Nevis	NTSC	M		Zaire	SECAM	K
St Lucia	NTSC	M		Zambia	PAL	B
St Vincent	NTSC	M		Zimbabwe	PAL	B
Samoa	NTSC	M				
Saudi Arabia	SECAM	B				
Senegal	SECAM	K				

Noise Measurement Bandwidth

When measuring or specifying Carrier-to-Noise Ratio, it is important to define the bandwidth in which the noise is specified.

The bandwidths for various television systems are as shown in the following table.

System	I	B, G	K1, L	D, K	M, N
Video bandwidth*	6.75	5.75	7.25	6.75	4.95
Noise bandwidth	5.08	4.75	5.58	5.75	4.00

* including lower sideband

AMPLIFIER OUTPUT TILT

This section contains graphs which show the RF output levels of amplifiers with a range of tilts, using both the ‘cable’ and the ‘linear’ shapes adopted by system operators.

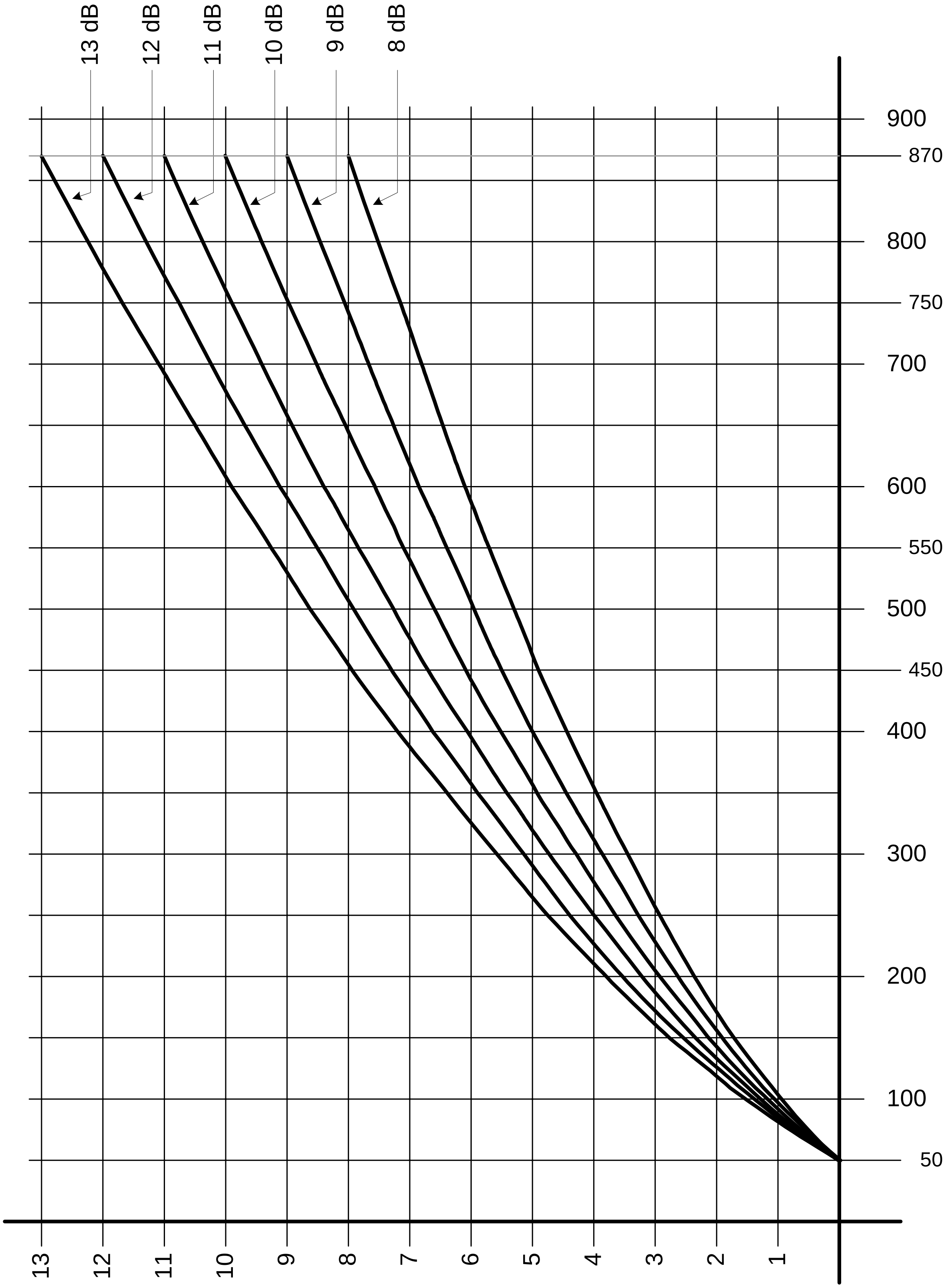
A ‘cable’ shape is designed to pre-emphasize the output of an RF amplifier to compensate for the characteristics of standard coaxial cable with foamed polyethylene dielectric. When plotted on a linear frequency scale, this characteristic exhibits a marked curvature. In recent years, the ‘linear’ shape has become popular, and as its name implies, it consists of a straight-line amplitude characteristic on a linear frequency scale.

The graphs in this section can be used as quick-reference tools in the following ways:

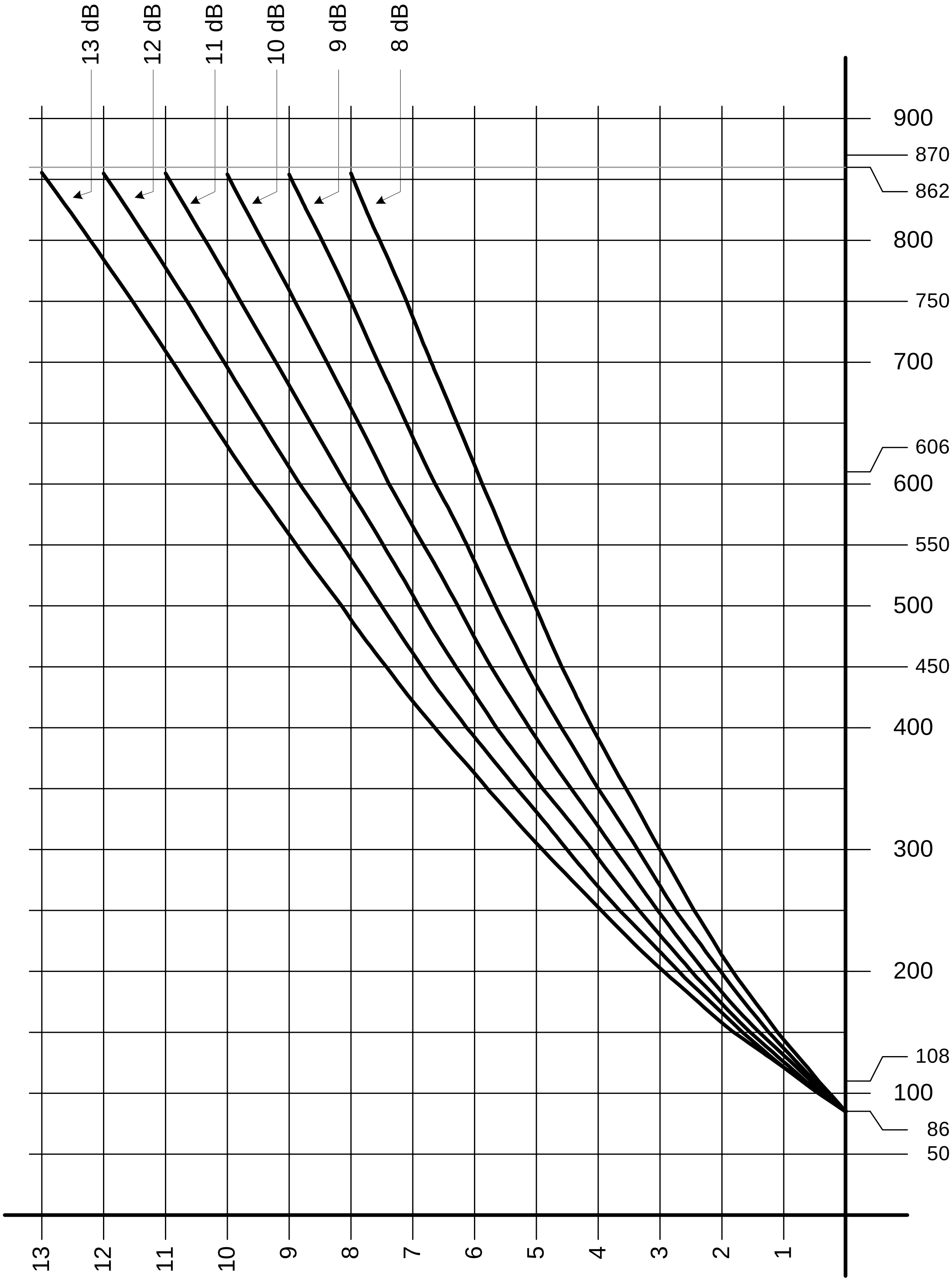
1. In existing systems, the amplitude of a signal at any frequency can be estimated.
2. When a bandwidth expansion is planned, it is common practice to maintain existing signal levels and to ‘project’ the amplifier output tilt (particularly in the feeder plant) to the new higher frequency. The graphs can be used to determine the levels of signals in the expanded frequency region.

The difference between a ‘cable’ and a ‘linear’ amplifier tilt can be significant, particularly when using a large tilt in 750 or 870 MHz systems. For example, in an 870 MHz system with a 12dB amplifier output tilt, the level of a signal at 550 MHz is approximately 1dB greater with a ‘cable’ tilt than with a ‘linear’ tilt. This results in increased CTB and CSO distortion products.

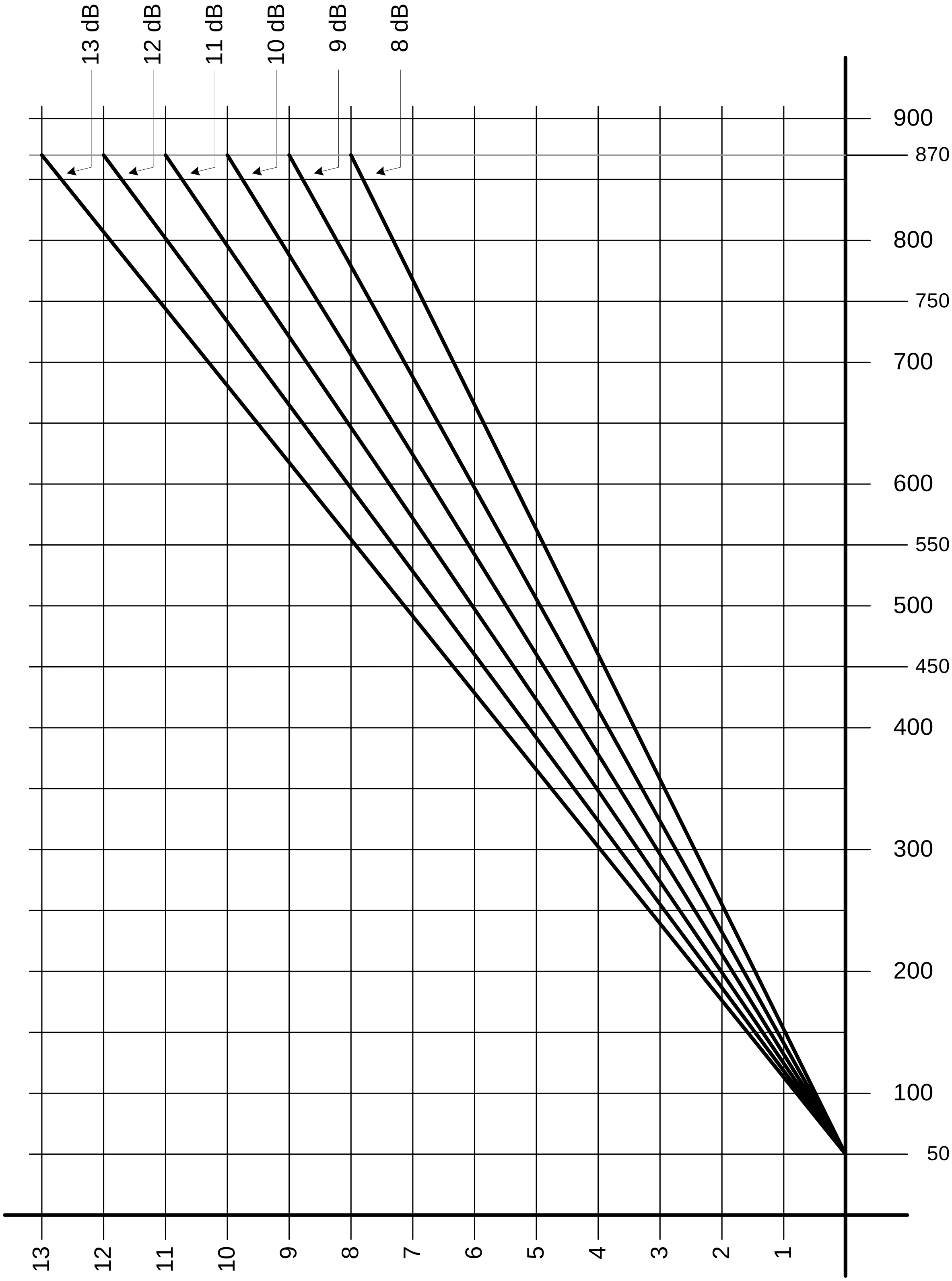
For North American systems, the graphs give overall tilt between 50 and 870 MHz. For European systems, the range is 86 to 862 MHz.



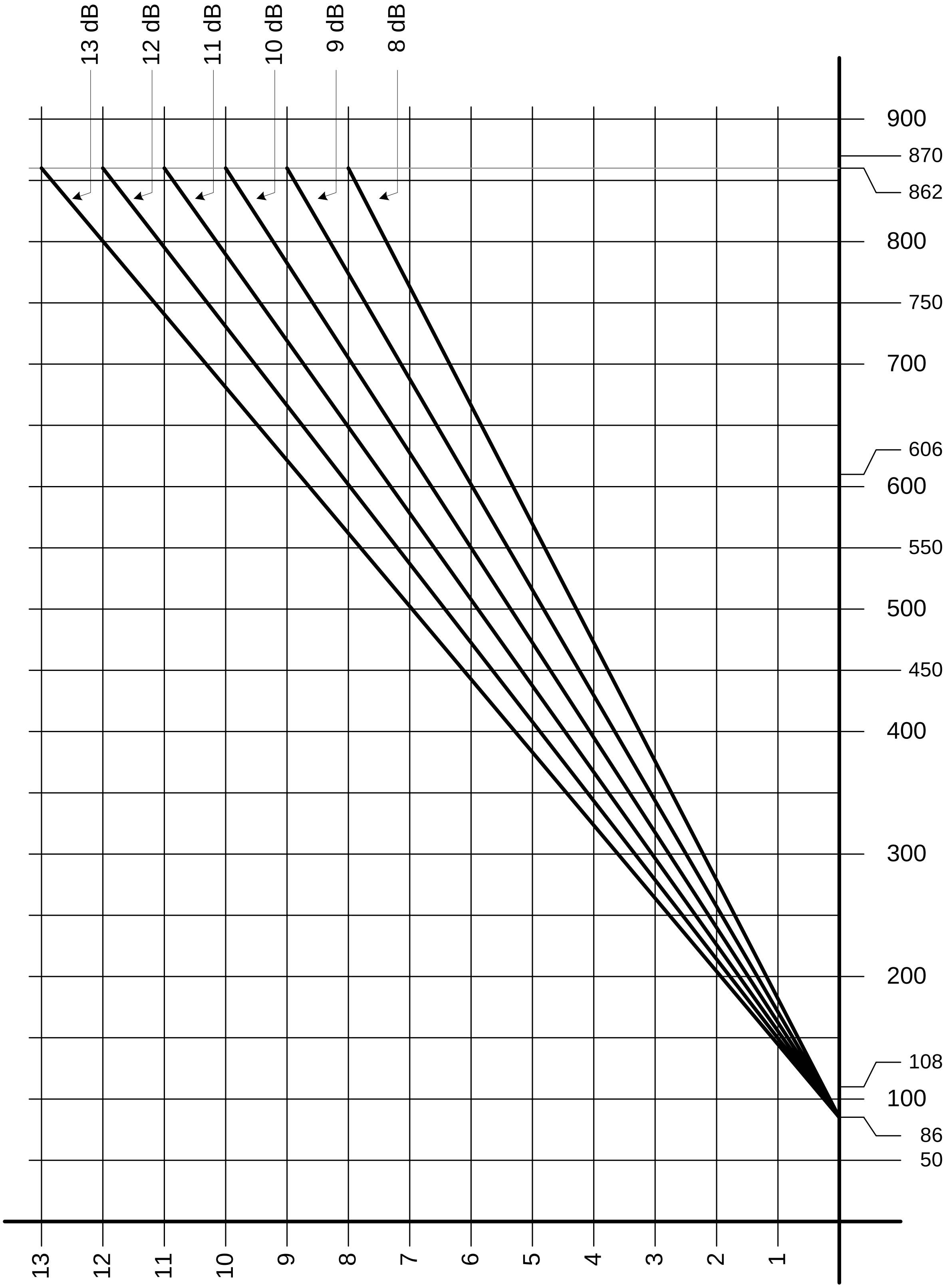
Cable tilt: North American systems



Cable tilt: European systems



Linear tilt: North American systems



Linear tilt: European systems

RF PASSIVES CHARACTERISTICS

The data in this section refer to Scientific-Atlanta outdoor taps and passives, and the Series 9900 TF Signal Manager modules. They are taken from Scientific-Atlanta published data sheets and, while every effort has been made to ensure accuracy in transcription, errors sometimes occur, and therefore these tables should be used for 'quick-reference' purposes only. For system design work, it is strongly recommended that the original data be used.

Surge-Gap™ Passives

The Scientific-Atlanta Surge-Gap™ series of passives are high-current devices for use in networks which may incorporate customer-premise equipment powered from the coaxial cable plant. They incorporate circuitry which allows them to tolerate voltage surges up to 6 kV.

Two- and Three-way Splitters

Part number:		712971 2-way balanced	712972 3-way balanced	712973 3-way unbalanced	
				Low	High
	Frequency				
Maximum insertion loss (dB)	5	4.4	6.1	7.5	3.9
	40	4.0	5.6	7.2	3.8
	50	4.0	5.6	7.2	3.8
	450	4.2	6.1	7.8	4.1
	550	4.3	6.2	7.9	4.2
	750	4.5	6.5	8.0	4.6
	870	4.7	6.6	8.1	4.7
	1000	4.9	6.9	8.3	4.9

NOTES:

Surge-Gap™ splitters can pass 60 or 90v 50/60Hz power at a current of 15A.
Return loss (all ports) is typically 18 dB (15 dB worst-case)

Surge-Gap™ Passives (continued)

Directional Couplers and Power Inserter

	Part number:	712968 DC-8	712969 DC-12	712970 DC-16	712974 Pwr Inserter
Maximum Insertion loss (dB)	**Frequency**				
	5	1.9	1.1	1.1	0.9
	40	1.7	1.1	1.0	0.7
	50	1.7	1.1	1.0	0.7
	450	1.9	1.2	1.1	0.7
	550	2.0	1.3	1.2	0.7
	750	2.2	1.5	1.4	0.8
	870	2.4	1.7	1.5	0.9
	1000	2.5	1.9	1.6	1.0
Maximum Tap loss (dB)	**Frequency**				
	5	9.3	13.8	17.0	
	40	9.1	13.3	16.5	
	50	9.1	13.3	16.6	
	450	9.1	13.2	16.7	
	550	9.1	13.1	16.6	
	750	9.3	13.2	17.0	
	870	9.4	13.2	17.1	
	1000	9.5	12.9	16.8	

NOTES:

DCs can pass 60 or 90v 50/60Hz power at a current of 15A.
Power Inserter can pass 60 or 90v 50/60Hz power at 20A through input port; 15A through output ports.
Return loss (all ports) is typically 18 dB (15 dB worst-case)

Multimedia Taps

These Scientific-Atlanta taps are also for use in networks which may incorporate customer-premise equipment powered from the coaxial cable plant. They are capable of carrying a continuous through-current of 12A, and they contain an AC/RF bypass switch that provides uninterrupted service to downstream customers when the faceplate is removed.

Multimedia Taps (continued)

Two-way Taps

		Tap value								
Model No. SAT MM 2-		**4**	**8**	**11**	**14**	**17**	**20**	**23**	**26**	**29**
	Frequency									
Maximum Insertion loss (dB)	5 - 10		3.2	1.9	1.3	1.1	0.8	0.8	0.8	0.8
	11 - 300		3.0	1.8	1.3	1.1	1.0	1.0	1.0	1.0
	301 - 400		3.6	2.5	1.8	1.6	1.4	1.4	1.4	1.4
	401 - 450		3.5	2.5	1.8	1.6	1.4	1.4	1.4	1.4
	451 - 600		3.6	2.6	1.8	1.6	1.4	1.4	1.4	1.4
	601 - 750		4.1	2.8	2.0	1.7	1.4	1.4	1.4	1.4
	751 - 900		4.0	3.3	2.2	1.9	1.7	1.7	1.7	1.7
	901 - 1000		4.5	3.4	2.4	2.0	1.9	1.9	1.9	1.9
	Frequency									
Tap loss (dB)	5 - 10	4.0	8.5	11.0	14.0	16.5	19.5	22.5	25.5	28.5
	11 - 1000	4.0	8.5	11.0	14.0	17.0	20.0	23.0	26.0	29.0

Four-way Taps

		Tap value							
Model No. SAT MM 4-		**8**	**11**	**14**	**17**	**20**	**23**	**26**	**29**
	Frequency								
Maximum Insertion loss (dB)	5 - 10		3.2	2.1	1.4	1.1	0.9	0.9	0.9
	11 - 300		3.0	2.1	1.4	1.1	0.9	0.9	0.9
	301 - 400		3.2	2.4	1.8	1.7	1.4	1.4	1.4
	401 - 450		3.6	2.5	1.9	1.7	1.4	1.4	1.4
	451 - 600		3.8	2.5	1.9	1.7	1.4	1.4	1.4
	601 - 750		4.3	2.8	2.0	1.7	1.4	1.4	1.4
	751 - 900		4.8	3.0	2.3	1.7	1.7	1.7	1.7
	901 - 1000		5.1	3.3	2.5	2.2	2.0	2.0	2.0
	Frequency								
Tap loss (dB)	5 - 10	8.0	12.0	14.5	16.5	19.5	22.5	25.5	28.5
	11 - 1000	8.0	12.0	14.5	17.0	20.0	23.0	26.0	29.0

Eight-way Taps

		Tap value						
Model No. SAT MM 8-		**11**	**14**	**17**	**20**	**23**	**26**	**29**
	Frequency							
Maximum Insertion loss (dB)	5 - 10		3.7	2.2	1.3	0.9	0.9	0.9
	11 - 300		3.9	2.0	1.4	1.1	1.1	1.1
	301 - 400		3.9	2.5	1.7	1.5	1.5	1.5
	401 - 450		4.1	2.6	1.9	1.6	1.6	1.6
	451 - 600		4.6	2.7	1.9	1.6	1.6	1.6
	601 - 750		5.1	2.9	1.9	1.6	1.6	1.6
	751 - 900		5.4	3.2	2.4	1.9	1.9	1.9
	901 - 1000		5.4	3.5	2.7	2.2	2.2	2.2
	Frequency							
Tap loss (dB)	5 - 10	11.0	15.0	17.5	20.0	23.0	26.0	29.0
	11 - 1000	11.5	15.5	18.0	20.5	23.5	26.5	29.0

NOTES:

The following taps are self-terminating:
Two-way, 4dB
Four-way, 8dB
Eight-way, 11dB
Taps are capable of passing 60 or 90v 60Hz power at a current of 12A.
Return loss (feeder ports): typically 18 dB (16 dB worst-case)

In-Line Equalizer (with Reverse Conditioning)

This unit, identical in size to a directional coupler, provides in-line equalization for feeders, compensating for 9 dB of cable. It also contains diplex filters and a reverse attenuator pad socket, allowing the user to increase the through-loss in the reverse path and thus to narrow the range of transmission levels (or ‘window’) from cable modems.

In the following table, the through-loss (insertion loss) of the LEQ-RC is specified with a 0 dB reverse pad installed. Pads are the standard Scientific-Atlanta type, available in 1 dB steps.

If reverse conditioning alone is required, the equalizer can be bypassed.

In-line Equalizer (continued)

	Frequency	Equalization mode	Equalization bypassed
Cable equalization (dB)	5 – 42	0	0
	51 - 750	9	0
Maximum Insertion loss (dB)	5	0.7	0.7
	10	0.6	0.6
	40	1.0	1.0
	42	1.3	1.3
	51	9.5	1.4
	54	9.3	1.3
	100	8.5	1.3
	450	5.1	1.3
	550	4.4	1.4
	750	3.0	1.7
	870	2.1	1.9
Flatness (dB)	5 - 42	± 0.65	± 0.65
	51 - 750	± 0.65	± 0.65

NOTES:

The LEQ-RC is capable of passing 60 or 90v 60Hz power at a current of 12A.
Return loss: typically 17 dB (16 dB worst-case)

Multimedia Stretch Taps

These Scientific-Atlanta taps provide the current-carrying capability and AC/RF bypass switch feature of the standard Multimedia units, but are offered in a 9-inch housing which permits system upgrades without the need for extension connectors. In addition, the tap value is selected by means of a plug-in directional coupler, which can be reversed if the direction of signal flow in the feeder must be changed.

Multimedia Stretch Taps (continued)

Two-way Taps

		Tap value								
Model No. SAT ST2-		**4**	**8**	**11**	**14**	**17**	**20**	**23**	**26**	**29**
	Frequency									
Maximum Insertion loss (dB)	5		3.4	2.0	1.3	1.0	0.9	0.9	0.9	0.9
	40		3.3	1.5	1.0	0.8	0.8	0.8	0.8	0.8
	50		3.3	1.5	1.0	0.8	0.8	0.8	0.8	0.8
	450		4.2	2.5	1.7	1.6	1.2	1.2	1.2	1.2
	550		4.0	2.6	1.8	1.6	1.3	1.3	1.3	1.3
	750		4.2	3.1	2.0	1.7	1.6	1.6	1.6	1.6
	860		4.6	3.2	2.1	1.8	1.7	1.7	1.7	1.7
	1000		4.9	3.2	2.2	2.0	1.7	1.7	1.7	1.7
	Frequency									
Tap loss (dB)	5 - 550	4.5	8.0	11.5	13.5	17.0	19.5	22.5	25.5	29.0
	550 - 1000	4.5	8.5	11.5	13.5	17.0	19.5	22.5	25.5	29.0

Four-way Taps

		Tap value							
Model No. SAT ST4-		**8**	**11**	**14**	**17**	**20**	**23**	**26**	**29**
	Frequency								
Maximum Insertion loss (dB)	5		3.4	2.0	1.3	1.0	0.9	0.9	0.9
	40		3.3	1.5	1.0	0.8	0.8	0.8	0.8
	50		3.3	1.5	1.0	0.8	0.8	0.8	0.8
	450		4.2	2.5	1.7	1.6	1.2	1.2	1.2
	550		4.0	2.6	1.8	1.6	1.3	1.3	1.3
	750		4.2	3.1	2.0	1.7	1.6	1.6	1.6
	860		4.6	3.2	2.1	1.8	1.7	1.7	1.7
	1000		4.9	3.2	2.2	2.0	1.7	1.7	1.7
	Frequency								
Tap loss (dB)	5 - 550	8.0	11.0	15.0	17.0	20.0	22.5	25.5	28.5
	550 - 750	8.0	11.5	15.0	17.0	20.0	22.5	25.5	28.5
	750 - 1000	8.5	12.0	15.0	17.0	20.0	22.5	25.5	28.5

Multimedia Stretch Taps (continued)

Eight-way Taps

		Tap value						
Model No. SAT MM 8-		**11**	**14**	**17**	**20**	**23**	**26**	**29**
	Frequency							
Maximum Insertion loss (dB)	5		3.4	2.0	1.3	1.0	0.9	0.9
	40		3.3	1.5	1.0	0.8	0.8	0.8
	50		3.3	1.5	1.0	0.8	0.8	0.8
	450		4.2	2.5	1.7	1.6	1.2	1.2
	550		4.0	2.6	1.8	1.6	1.3	1.3
	750		4.2	3.1	2.0	1.7	1.6	1.6
	860		4.6	3.2	2.1	1.8	1.7	1.7
	1000		4.9	3.2	2.2	2.0	1.7	1.7
	Frequency							
Tap loss (dB)	5 - 750	11.5	14.0	17.5	20.0	23.0	26.0	29.0
	750 - 860	12.0	15.5	18.0	20.0	23.0	26.0	29.0
	860 - 1000	12.5	16.0	18.5	20.5	23.0	26.0	29.0

NOTES:

The following taps are self-terminating:
Two-way, 4dB
Four-way, 8dB
Eight-way, 11dB
Taps are capable of passing 60 or 90v 60Hz power at a current of 12A.
Return loss (feeder ports): typically 16 dB, 10 to 1000 MHz.

Series 9900 RF Signal Manager

This product-line comprises a family of modular splitters, combiners and couplers which allow the construction of RF signal handling networks in Headend or Hub environments. A simple 19-inch rack-mount chassis provides a housing for the modules and permits RF cabling to be laid out in a neat and uncluttered manner. Modules are color-coded for easy identification.

Separate modules are provided for downstream and upstream frequency ranges.

Two-way splitter/combiner modules

	Reverse	Forward			
Freq. range (MHz):	**5-70**	**50-550**	**550-750**	**750-870**	**870-1000**
Insertion loss (dB)	3.7 max 3.3 typ	4.0 max 3.7 typ	4.2 max 3.8 typ	4.3 max 3.9 typ	4.5 max 4.2 typ
Return loss (dB), ports 1 and 2	≥ 24	≥ 23	≥ 23	≥ 23	≥ 21
Return loss (dB), common port	≥ 24	≥ 23	≥ 23	≥ 23	≥ 21
Port-to-port isolation (dB)	≥ 32	≥ 32	≥ 32	≥ 32	≥ 30
Ingress isolation (dB)	100 min 110 typ	100 min 110 typ	100 min 110 typ	100 min 110 typ	100 min 110 typ
Dual devices isolation (dB)	> 70	> 70	> 65	> 60	> 60

Four-way splitter/combiner modules

	Reverse	Forward			
Freq. range (MHz):	**5-70**	**50-550**	**550-750**	**750-870**	**870-1000**
Insertion loss (dB)	7.1 max 6.8 typ	8.0 max 7.6 typ	8.2 max 7.7 typ	8.3 max 7.8 typ	8.4 max 7.9 typ
Return loss (dB), ports 1 to 4	25 min 30 typ	22 min 26 typ	22 min 26 typ	22 min 26 typ	22 min 26 typ
Return loss (dB), common port	25 min 28 typ	20 min 24 typ	20 min 24 typ	20 min 24 typ	20 min 24 typ
Port-to-port isolation (dB)	32 min 38 typ	30 min 34 typ	30 min 34 typ	30 min 34 typ	30 min 34 typ
Ingress isolation (dB)	100 min 110 typ	100 min 110 typ	100 min 110 typ	100 min 110 typ	100 min 110 typ

Eight-way splitter/combiner modules

	Reverse	Forward			
Freq. range (MHz):	**5-70**	**50-550**	**550-750**	**750-870**	**870-1000**
Insertion loss (dB)	10.6 max 10.2 typ	11.8 max 11.3 typ	12.2 max 11.5 typ	12.4 max 11.9 typ	12.8 max 12.0 typ
Return loss (dB), ports 1 to 8	25 min 30 typ	22 min 26 typ	22 min 26 typ	22 min 26 typ	22 min 26 typ
Return loss (dB), common port	25 min 28 typ	20 min 24 typ	20 min 24 typ	20 min 24 typ	20 min 24 typ
Port-to-port isolation (dB)	32 min 38 typ	30 min 34 typ	30 min 34 typ	30 min 34 typ	30 min 34 typ
Ingress isolation (dB)	100 min 110 typ	100 min 110 typ	100 min 110 typ	100 min 110 typ	100 min 110 typ

10dB directional coupler modules

	Reverse	Forward			
Freq. range (MHz):	**5-70**	**50-550**	**550-750**	**750-870**	**870-1000**
Insertion loss (dB)	1.0 max 0.7 typ	1.3 max 1.0 typ	1.4 max 1.1 typ	1.6 max 1.2 typ	1.8 max 1.3 typ
Input to tap ins. loss (dB)	9.6 min 10.0 max	9.5 min 10.0 max	9.5 min 10.0 max	9.5 min 10.0 max	9.3 min 10.0 max
Return loss (dB), all ports	≥ 24	≥ 23	≥ 23	≥ 23	≥ 21
Port-to-port isolation (dB)	≥ 31	≥ 31	≥ 31	≥ 31	≥ 31
Ingress isolation (dB)	100 min 110 typ	100 min 110 typ	100 min 110 typ	100 min 110 typ	100 min 110 typ
Dual devices isolation (dB)	> 70	> 70	> 65	> 60	> 60

20dB directional coupler modules

	Reverse	Forward			
Freq. range (MHz):	**5-70**	**50-550**	**550-750**	**750-870**	**870-1000**
Insertion loss (dB)	0.7 max 0.4 typ	0.9 max 0.5 typ	1.0 max 0.6 typ	1.0 max 0.6 typ	1.2 max 0.8 typ
Input to tap ins. loss (dB)	19.6 min 20.0 max	19.5 min 20.0 max	19.5 min 20.0 max	19.5 min 20.0 max	19.3 min 20.0 max
Return loss (dB), all ports	≥ 24	≥ 23	≥ 23	≥ 23	≥ 21
Port-to-port isolation (dB)	≥ 39	≥ 39	≥ 39	≥ 39	≥ 35
Ingress isolation (dB)	100 min 110 typ	100 min 110 typ	100 min 110 typ	100 min 110 typ	100 min 110 typ
Dual devices isolation (dB)	> 70	> 70	> 65	> 60	> 60

COAXIAL CABLE CHARACTERISTICS

The data in this section are taken from the manufacturers' published data sheets. While every effort has been made to ensure accuracy in transcription, errors sometimes occur, and therefore these tables should be used for 'quick-reference' purposes only. For system design work, it is strongly recommended that the manufacturers' original data be used.

All figures in the cable loss tables represent losses at 68°F (20°C). As temperature decreases from this reference, cable attenuation decreases by approximately 1.0% for every 10°F (5.56°C) drop in temperature.

As temperature increases from the 68°F reference, cable attenuation increases by approximately 1.2% for every 10°F (5.56°C) rise in temperature.

Trilogy Communications MC^2

Cable dia. (in):	0.440		0.500		0.650		0.750		1.00	
dB loss per 100	**ft**	**m**	**ft**	**m**	**ft**	**m**	**ft**	**m**	**ft**	**m**
Frequency (MHz)										
5	0.17	0.56	0.14	0.46	0.11	0.36	0.10	0.33	0.07	0.23
55	0.56	1.84	0.48	1.57	0.38	1.25	0.34	1.12	0.24	0.79
350	1.44	4.72	1.23	4.04	0.99	3.25	0.86	2.82	0.65	2.13
400	1.54	5.05	1.32	4.33	1.06	3.48	0.91	2.99	0.70	2.30
450	1.64	5.38	1.40	4.60	1.13	3.71	0.97	3.18	0.74	2.43
550	1.81	5.94	1.55	5.09	1.25	4.10	1.08	3.54	0.82	2.69
600	1.90	6.23	1.63	5.36	1.34	4.41	1.11	3.65	0.87	2.86
750	2.13	6.99	1.83	6.00	1.50	4.92	1.25	4.10	0.97	3.18
800	2.22	7.30	1.91	6.28	1.56	5.13	1.30	4.28	1.02	3.36
900	2.36	7.76	2.03	6.68	1.67	5.49	1.39	4.57	1.09	3.59
1000	2.49	8.19	2.15	7.07	1.77	5.81	1.47	4.82	1.16	3.82
Loop resistance per 1000	**ft**	**m**	**ft**	**m**	**ft**	**m**	**ft**	**m**	**ft**	**m**
Copper-clad aluminum center conductor	1.95	6.40	1.55	5.09	1.00	3.28	0.69	2.26	0.41	1.35

Maximum attenuation data taken from Manufacturer's data sheets. Contact Manufacturer for detailed information.

Coaxial Cable Characteristics (cont'd)

Times Fiber Communications T10 cable

Cable dia. (in):	0.500		0.625		0.750		0.875		1.00	
dB loss per 100	**ft**	**m**	**ft**	**m**	**ft**	**m**	**ft**	**m**	**ft**	**m**
Frequency (MHz)										
5	0.16	0.52	0.13	0.43	0.11	0.36	0.09	0.30	0.08	0.26
55	0.55	1.80	0.45	1.46	0.37	1.21	0.32	1.04	0.29	0.95
350	1.43	4.69	1.18	3.87	0.97	3.18	0.84	2.76	0.78	2.56
400	1.53	5.02	1.27	4.17	1.05	3.44	0.91	2.99	0.84	2.76
450	1.63	5.35	1.35	4.43	1.12	3.67	0.97	3.18	0.90	2.95
550	1.82	5.97	1.51	4.95	1.25	4.10	1.09	3.58	1.01	3.31
600	1.91	6.27	1.58	5.18	1.31	4.30	1.14	3.74	1.06	3.48
750	2.16	7.09	1.79	5.87	1.48	4.86	1.29	4.23	1.21	3.97
870	2.35	7.69	1.95	6.40	1.61	5.28	1.41	4.83	1.33	4.35
1000	2.53	8.30	2.11	6.92	1.74	5.71	1.53	5.02	1.44	4.72
Loop resistance per 1000	**ft**	**m**	**ft**	**m**	**ft**	**m**	**ft**	**m**	**ft**	**m**
Copper-clad aluminum center conductor	1.70	5.58	1.10	3.61	0.75	2.46	0.56	1.80	0.41	1.40

Maximum attenuation data taken from Manufacturer's data sheets. Contact Manufacturer for detailed information.

CommScope Parameter III

Cable dia. (in):	0.500		0.625		0.750		0.875		1.00	
dB loss per 100	**ft**	**m**	**ft**	**m**	**ft**	**m**	**ft**	**m**	**ft**	**m**
Frequency (MHz)										
5	0.16	0.52	0.13	0.43	0.11	0.36	0.09	0.30	0.08	0.26
30	0.40	1.31	0.32	1.05	0.26	0.85	0.23	0.75	0.21	0.69
55	0.54	1.77	0.46	1.51	0.37	1.21	0.33	1.08	0.31	1.02
350	1.43	4.69	1.18	3.87	0.97	3.18	0.84	2.76	0.78	2.56
400	1.53	5.02	1.27	4.17	1.05	3.44	0.91	2.99	0.84	2.76
450	1.63	5.35	1.35	4.43	1.12	3.67	0.97	3.18	0.90	2.95
550	1.82	5.97	1.50	4.92	1.24	4.07	1.08	3.54	1.01	3.31
600	1.91	6.27	1.58	5.18	1.31	4.30	1.14	3.74	1.06	3.48
750	2.16	7.09	1.78	5.84	1.48	4.86	1.29	4.23	1.21	3.97
865	2.34	7.68	1.93	6.33	1.61	5.28	1.41	4.63	1.34	4.40
1000	2.52	8.27	2.07	6.79	1.74	5.71	1.53	5.02	1.44	4.72
Loop resistance per 1000	**ft**	**m**	**ft**	**m**	**ft**	**m**	**ft**	**m**	**ft**	**m**
Copper-clad aluminum	1.72	5.64	1.10	3.51	0.76	2.49	0.55	1.81	0.40	1.31
Solid Copper	1.20	3.96	0.79	2.59	0.56	1.83	0.41	1.35	-	-

Maximum attenuation data taken from Manufacturer's data sheets. Contact Manufacturer for detailed information.

Coaxial Cable Characteristics (cont'd)

CommScope Quantum Reach

Cable dia. (in):	0.540		0.715		0.860		1.125	
dB loss per 100	**ft**	**m**	**ft**	**m**	**ft**	**m**	**ft**	**m**
Frequency (MHz)								
5	0.14	0.46	0.11	0.36	0.09	0.30	0.07	0.23
30	0.34	1.12	0.27	0.89	0.23	0.75	0.17	0.56
55	0.47	1.54	0.36	1.18	0.32	1.05	0.23	0.76
350	1.23	4.03	0.97	3.18	0.83	2.72	0.65	2.13
400	1.32	4.33	1.05	3.44	0.88	2.89	0.70	2.30
450	1.40	4.59	1.12	3.67	0.95	3.12	0.75	2.46
550	1.56	5.12	1.25	4.10	1.06	3.48	0.84	2.76
600	1.64	5.38	1.31	4.30	1.10	3.61	0.89	2.92
750	1.85	6.07	1.49	4.89	1.24	4.07	1.01	3.31
865	2.00	6.56	1.62	5.31	1.33	4.36	1.11	3.64
1000	2.17	7.12	1.75	5.74	1.44	4.72	1.20	3.94
Loop resistance per 1000	**ft**	**m**	**ft**	**m**	**ft**	**m**	**ft**	**m**
Copper-clad aluminum center conductor	1.61	5.28	0.997	3.27	0.724	2.37	0.42	1.38

Maximum attenuation data taken from Manufacturer's data sheets.
Contact Manufacturer for detailed information.

Times Fiber Communications T10 Drop Cable

Cable type:	RG-59		RG-6		RG-611		RG-11	
dB loss per 100	**ft**	**m**	**ft**	**m**	**ft**	**m**	**ft**	**m**
Frequency (MHz)								
5	0.81	2.66	0.61	2.00	0.56	1.84	0.36	1.18
30	1.45	4.76	1.17	3.84	1.00	3.28	0.75	2.46
50	1.78	5.84	1.44	4.72	1.20	3.94	0.93	3.05
350	4.48	14.7	3.65	12.0	2.98	9.77	2.36	7.74
400	4.81	15.8	3.92	12.9	3.20	10.5	2.53	8.30
450	5.13	16.8	4.17	13.7	3.41	11.2	2.69	8.82
550	5.72	18.8	4.65	15.3	3.80	12.5	3.01	9.87
600	6.00	19.7	4.87	16.0	3.99	13.1	3.16	10.4
750	6.78	22.2	5.50	18.0	4.50	14.8	3.58	11.7
862	7.33	24.0	5.93	19.5	4.85	15.9	3.88	12.7
900	7.50	24.6	6.07	19.9	4.96	16.3	3.97	13.0
950	7.73	25.4	6.25	20.5	5.11	16.8	4.10	13.4
1000	7.95	26.1	6.43	21.1	5.25	17.2	4.23	13.9
Loop resistance per 1000	**ft**	**m**	**ft**	**m**	**ft**	**m**	**ft**	**m**
Copper-clad steel center conductor; QUADSHIELD	54.5	179	34.1	112	23.5	77.1	16.1	52.8

Maximum attenuation data taken from Manufacturer's data sheets.
Contact Manufacturer for detailed information.

Loss Ratio Table

The following table provides the ratios of cable losses between the commonly-encountered upper frequency limits of CATV systems. Using this table, the increase in cable loss encountered during a 'drop-in' upgrade can be simply calculated. For example, if a 550 MHz system is to be upgraded to 750 MHz, and trunk amplifiers are currently spaced at 22 dB intervals, the new cable loss will be (22 x 1.19) = 26.18 dB

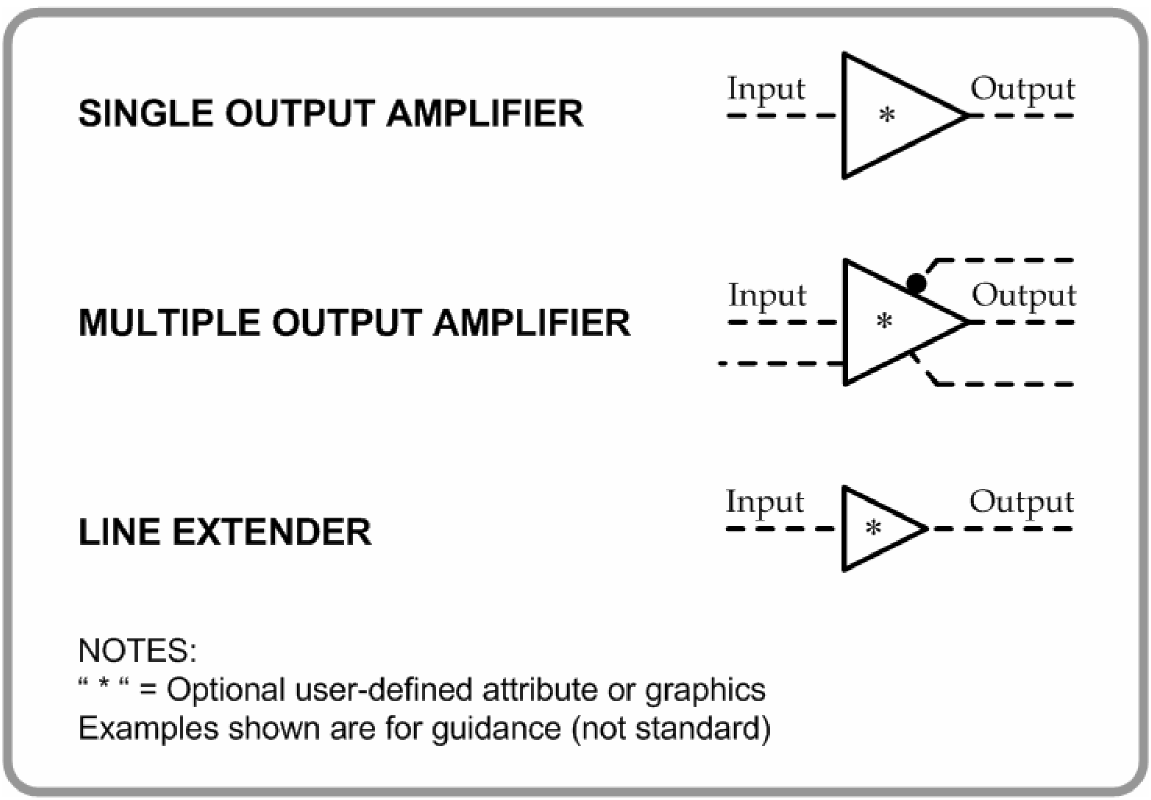
Upgrade to:	**450**	**550**	**600**	**625**	**750**	**870**	**1000**
from							
216	1.47	1.64	1.73	1.77	1.96	2.14	2.30
270	1.33	1.48	1.56	1.59	1.76	1.93	2.08
300	1.26	1.40	1.48	1.51	1.67	1.82	1.97
330	1.18	1.32	1.39	1.42	1.57	1.72	1.85
400	1.07	1.19	1.25	1.28	1.42	1.55	1.67
450		1.11	1.17	1.20	1.33	1.45	1.56
550			1.05	1.08	1.19	1.30	1.40
600				1.02	1.13	1.24	1.33
625					1.11	1.21	1.30
750						1.09	1.18
870							1.08

(Loss ratios are calculated using the CommScope Parameter III cable specifications, and taking an average over the range of cable diameters)

STANDARD HFC GRAPHIC SYMBOLS

The following symbols are used in to identify HFC components in system design maps and schematics. They are taken from the Society of Cable Telecommunications Engineers (SCTE) standard, ANSI/SCTE 87-1 2003 (formerly CMS WG6-0001); “Graphic Symbols For Cable Telecommunications Part 1: HFC Symbols”. Note that only the RF and optical component symbols are reproduced here; that is, the items in Sections 8 through 18 of the Standard.

AMPLIFIERS

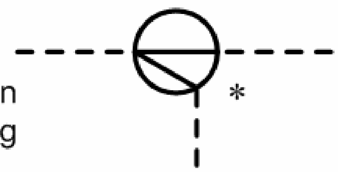


SPLITTING DEVICES

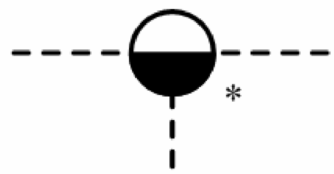
2-WAY SPLITTER

3-WAY SPLITTER
Dot shows high output leg, if unbalanced

DIRECTIONAL COUPLER
* Model or value designations are to be shown adjacent or inside symbols. The high-loss leg leaves the angular half of the symbol.



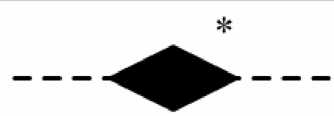
(alternate)



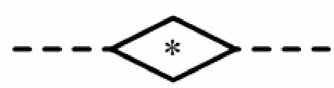
NOTES:
Indoor drop splits may have additional user-defined symbols.

LINE DEVICES

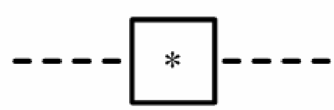
IN-LINE EQUALIZER



(alternate)



SPLICE

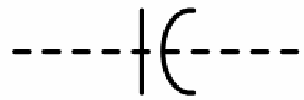


(alternate)

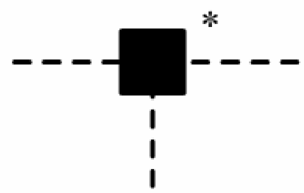
NOTES:
“ * “ = Optional user-defined attribute or graphics

POWERING DEVICES

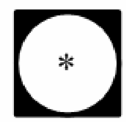
AC POWER BLOCK



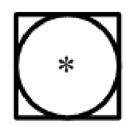
AC POWER INSERTER
" * " = Optional user-defined attributes



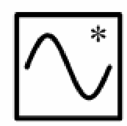
STANDBY POWER SUPPLY
" * " = Optional information: voltage, current, load, power supply name, status monitor



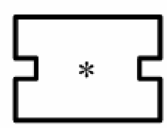
NON-STANDBY POWER SUPPLY
" * " = Optional information: voltage, current, load, power supply name, status monitor



(alternate)



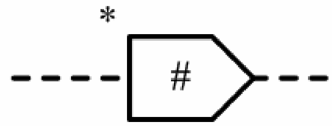
CENTRALIZED POWER SUPPLY
" * " = Optional information: voltage, current, load, power supply name, status monitor



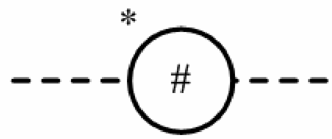
NOTES:
Additional graphics such as a circle around the symbol may also be used to designate new/existing locations

SUBSCRIBER TAPS

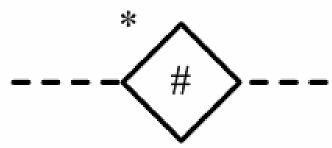
1-OUTPUT DIRECTIONAL TAP



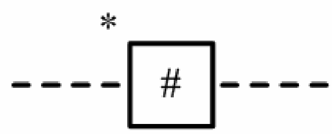
2-OUTPUT DIRECTIONAL TAP



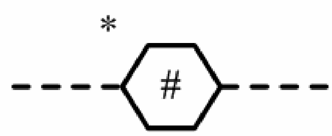
3-OUTPUT DIRECTIONAL TAP



4-OUTPUT DIRECTIONAL TAP



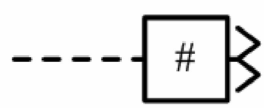
8-OUTPUT DIRECTIONAL TAP



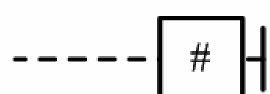
NOTES:
“ # “ Represents value of tap
“ * “ Represents value of pad, cable equalizer, addressable or telephony tap
Indoor taps may have additional user-defined symbols

LINE TERMINATORS

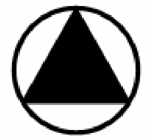
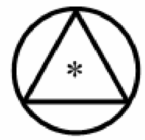
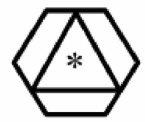
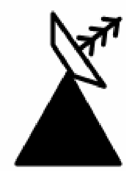
RF TERMINATOR
(4-output tap shown for example only)



SELF-TERMINATING TAP
Applies to lowest-value tap within any family group.
(4-output tap shown for example only)
Self-terminating tap may be shown without symbol



SIGNAL PROCESSING LOCATIONS

HEADEND Location where the highest level of signal Processing takes place	
PRIMARY HUB In multi-level networks, a signal processing location connected between the Headend and secondary hubs or nodes	
SECONDARY HUB In multi-level networks, a signal processing location connected between the primary hub and the node	
WIRELESS HUB	

NOTES:
" * " = Optional user-defined attributes

COAXIAL CABLES – typical symbology

1.000 inch (25.4 mm)	
0.875 inch (22.2 mm)	
0.750 inch (19.2 mm)	
0.625 inch (15.9 mm)	
0.500 inch (12.7 mm)	
0.412 inch (10.5 mm)	

COAXIAL CABLES – optional symbology (examples)

(For specialty cables and cables listed in ANSI/SCTE 15, 2001)

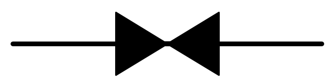
0.750 inch Parameter III*

0.540 inch Quantum Reach*

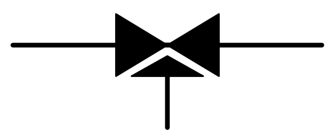
* 'Parameter III' and 'Quantum Reach' are Registered Trade-Marks of CommScope, Inc.

OPTICAL SPLICE SYMBOLS

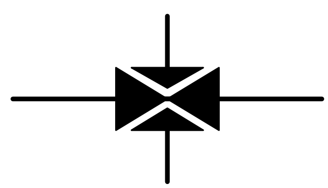
2-WAY SPLICE



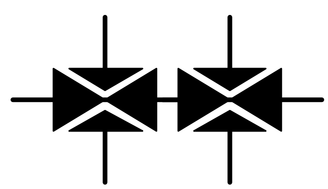
3-WAY SPLICE



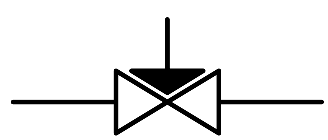
4-WAY SPLICE



> 4-WAY SPLICE



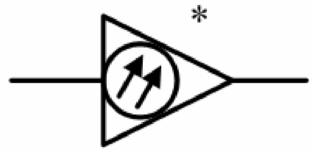
MID-ENTRY SPLICE / RING CUT



OPTICAL DEVICES

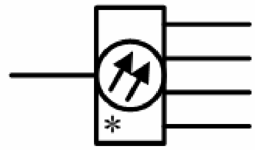
OPTICAL AMPLIFIER

" * " Indicates the gain (dB)



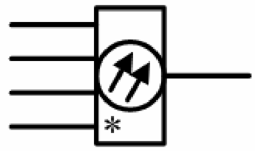
DEMULTIPLEXER

" * " Indicates number of outputs



MULTIPLEXER

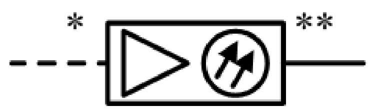
" * " Indicates number of inputs



OPTICAL TRANSMITTER

" * " = Input RF level

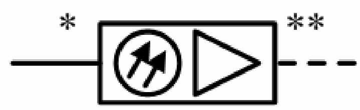
" ** " = Output optical power



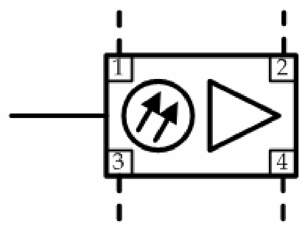
OPTICAL NODE

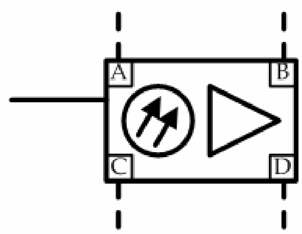
" * " = Input optical power

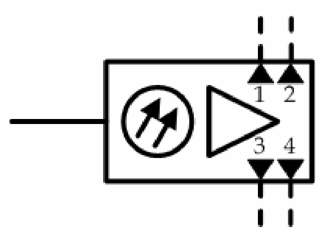
" ** " = Output RF level



(examples)

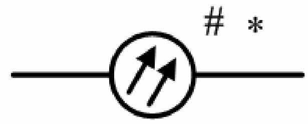






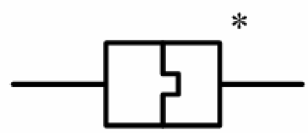
MISCELLANEOUS OPTICAL SYMBOLS

OPTICAL FIBER CABLE
“ # “ Indicates the fiber count
“ * “ Denotes user-defined attributes

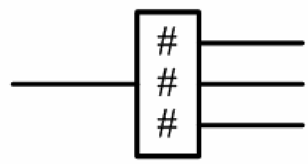


OPTICAL STORAGE LOOP
“ * “ Denotes user-defined attributes

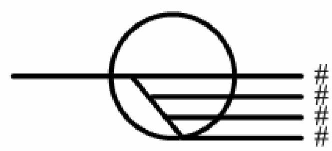
CONNECTOR
“ * “ = Connector type



SPLITTER
“ # “ = Percent or dB loss



(alternate)
Symbol shown with optional outputs
to be added as necessary



DTV STANDARDS WORLDWIDE

NOTE: DTV (Digital TeleVision) systems are deployed in several countries, in accordance with a variety of Standards. Many other countries and regions are in the process of deploying such systems, or are still studying the suitability of the various Standards to their local needs. Bearing this in mind, it should be noted that the information contained in this section may only be regarded as comprehensive on the date of publication of this edition of the Broadband DataBook. (Edition 14, May 2004).

1. TERRESTRIAL TRANSMISSION

NORTH AMERICA (incl. MEXICO and parts of SOUTH AMERICA), TAIWAN & S. KOREA

RF Transmission system characteristics are defined by the ATSC (Advanced Television Systems Committee) Standard, Doc. A/53B, as amended. Information on this Standard may be found at www.atsc.org and at www.atscforum.org

In Annex 'D', two transmission modes are defined. The 'terrestrial broadcast mode' uses 8 VSB (eight-level Vestigial Side-Band), and the 'high data-rate mode' uses 16 VSB.

8 VSB supports a payload of approximately 19.28 Mbps in a 6 MHz channel, and 16 VSB supports approximately 38.57 Mbps. In both cases, the input to the transmission system consists of 188-byte MPEG-compatible transport multiplex packets; the primary difference lies in the number of transmitted levels (16 vs 8).

Parts of SOUTH AMERICA (Argentina, Brazil, Chile, Colombia and Equador), EUROPE, AUSTRALIA, INDIA, SOUTH EAST ASIA AND CHINA

The standards used in these areas are derived from the work of the DVB (Digital Video Broadcasting) project, which has resulted in suite of digital

Terrestrial transmission (cont'd)

television standards for satellite, cable and terrestrial transmission. For the latter application, the standard is referred to as DVB-T.

DVB provides technical recommendations to the European Broadcasting Union (EBU), and the standards are formalized and published by the European Telecommunications Standards Institute (ETSI). In the case of DVB-T, the standard is ETSI EN 300 744.

The terrestrial transmission RF technology is COFDM, or Coded Orthogonal Frequency Division Multiplex modulation. The serial bit-stream, instead of modulating a single carrier, is distributed over many closely-spaced individual carriers, making the transmission relatively immune to multipath distortion and narrowband interfering signals.

The standard provides for transmission in channels of 6, 7 or 8 MHz bandwidth. As with the ATSC standard, MPEG-2 video and audio coding is the basis of the DVB-T.

The individual carriers in the COFDM spectrum can be modulated using QPSK, 16-QAM or 64-QAM. Furthermore, the user can select from a range of convolutional code rates and inter-symbol guard intervals, giving rise to a large range of usable data-rates. The lowest and highest rates for the three primary modulation schemes and for 6, 7 and 8 MHz channel widths are presented in Table 9.1

Table 9.1: Ranges of usable data-rates for COFDM transmissions

	6 MHz channel		7 MHz channel		8 MHz channel	
Modulation	lowest	highest	lowest	highest	lowest	highest
QPSK	3.732	7.917	4.354	9.237	4.98	10.56
16-QAM	7.465	15.834	8.709	18.473	9.95	21.11
64-QAM	11.197	23.751	13.063	27.710	14.93	31.67

Terrestrial transmission (cont'd)

JAPAN

A variant of the DVB-T standard, referred to as ISDB-T (Terrestrial Integrated Services Digital Broadcasting) has been developed in Japan by the Japanese Digital Broadcasting Experts Group (DiBEG). The major difference lies in the adoption of a data segmentation system, which allows a mixture of services such as radio, HDTV and standard-definition TV to be allocated segments of the overall bandwidth on a flexible basis.

WORLDWIDE

The various terrestrial digital transmission standards have been ratified by ITU (International Telecommunications Union) as ITU-R BT.1306. However, portions of South America, Southeast Asia and virtually the whole of Africa have not formally adopted any Standard.

2. SATELLITE TRANSMISSION

ALL AREAS

The fundamental standard for satellite transmission of digital video signals is defined by DVB-S, which is the earliest of the DVB standards and the most widely accepted.

In Europe, the EBU passed the DVB-S recommendations to ETSI, which published the standard as ETSI EN 300 421.

In North America, 'Modulation and Coding Requirements for Digital TV Applications Over Satellite' is an Advanced Television Systems Committee standard, set forth in ATSC Doc. A/80. This standard is almost identical to EN 300 421, and differs primarily in the fact that it allows the transmission of arbitrary data-streams, as well as MPEG-2 transport streams, and defines the use of modulation schemes other than QPSK.

Worldwide, the relevant set of Recommendations is contained in the International Telecommunications Union (ITU) document ITU-R BO.1516, "Digital multiprogramme television systems for use by satellites operating in the 11/12 GHz frequency range". This document describes four fundamental systems, with many components in common. System 'A' is described in an earlier recommendation, ITU-R BO.1211, which is actually the ETSI standard referred to above (ETSI EN 300 421). Systems 'B' and 'C' are described in ITU-R BO.1294 and refer to Direct Satellite Systems (DSS) services, and System 'D' defines the satellite component of the Japanese ISDB system. It is fully defined in ITU-R BO.1408.

Transmission rates for various satellite transponder bandwidths and convolutional code rates are shown in Tables 9.2 and 9.3, which are taken from the ETSI standard (ETSI EN 300 421), and the ATSC A/80 standard, respectively. As mentioned above, these standards are very similar and the difference in the transmission rates, shown in the two tables, is due solely to the way in which the Symbol Rate is defined.

Satellite transmission (cont'd)

In the ETSI standard, the symbol rate is obtained by dividing the 3dB bandwidth by 1.28, whereas the ATSC standard uses a factor of 1.35. These factors are derived from the modulation roll-off, and the ATSC figure represents a more conservative assumption.

Table 9.2: Usable data-rates (ETSI standard)

		Usable bit-rate (Mbit/sec), QPSK modulation				
Transponder 3dB bandwidth (MHz)	Symbol rate (Mbaud)	1/2 convol. encoding	2/3 convol. encoding	3/4 convol. encoding	5/6 convol. encoding	7/8 convol. encoding
54	42.2	38.9	51.8	58.3	64.8	68.0
46	35.9	33.1	44.2	49.7	55.2	58.0
40	31.2	28.8	38.4	43.2	48.0	50.4
36	28.1	25.9	34.6	38.9	43.2	45.4
33	25.8	23.8	31.7	35.6	39.6	41.6
30	23.4	21.6	28.8	32.4	36.0	37.8
27	21.1	19.4	25.9	29.2	32.4	34.0
26	20.3	18.7	25.0	28.1	31.2	32.8

Table 9.3: Usable data-rates (ATSC standard)

		Usable bit-rate (Mbit/sec), QPSK modulation				
Available 3dB bandwidth (MHz)	Symbol rate (Mbaud)	1/2 convol. encoding	2/3 convol. encoding	3/4 convol. encoding	5/6 convol. encoding	7/8 convol. encoding
72	53.33	49.15	65.53	73.73	81.92	86.01
54	40.00	36.86	49.15	55.29	61.44	64.51
46	34.07	31.40	41.87	47.10	52.34	54.95
41	30.37	27.99	37.32	41.98	46.65	48.98
36	26.67	24.58	32.77	36.86	40.96	43.01
33	24.44	22.53	30.04	33.79	37.55	39.42
30	22.22	20.48	27.31	30.72	34.13	35.84
27	20.00	18.43	24.58	27.65	30.72	32.25
18	13.33	12.29	16.38	18.43	20.48	21.50
15	11.11	10.24	13.65	15.36	17.07	17.92
12	8.89	8.19	10.92	12.29	13.65	14.34
9	6.67	6.14	8.19	9.22	10.24	10.75
6	4.44	4.10	5.46	6.14	6.83	7.17
4.5	3.33	3.07	4.10	4.61	5.12	5.38
3	2.22	2.05	2.73	3.07	3.41	3.58
1.5	1.11	1.02	1.37	1.54	1.71	1.79

3. CABLE SYSTEM TRANSMISSION

ALL AREAS

As with satellite and terrestrial digital video systems, the basic payload in digital cable systems is the MPEG-2 transport stream.

Internationally, the recommendations of the ITU are definitive. The relevant document is ITU Recommendation J.83, which describes the method of digital transmission for four television systems. Systems 'A' and 'B' are intended for deployments in Europe and North America, respectively, and are transparent to signals derived from satellite transmissions. Both define a high-order QAM modulation scheme for transmission via coaxial cable. System 'C' is intended to be compatible with terrestrial transmissions or ISDN networks; the modulation scheme is 64QAM and is optimized for 6 MHz channels. System 'D' addresses specifically North American systems, and describes a 16-VSB modulation scheme.

The North American system is also defined in ANSI/SCTE 07 2000 (formerly SCTE DVS 031), which was ratified by ITU as Recommendation J.83, Annex 'B'.

The European system is also defined in ETSI EN 300 429, which was ratified by ITU as Recommendation J.83, Annex 'A'. However, the ETSI standard also allows modulation using 128QAM and 256QAM.

Since the most common cable modulation scheme is QAM, examples of symbol rates and data transmission rates for various orders of QAM are given in Table 9.4.

Cable transmission (cont'd)

Table 9.4: Examples of usable data-rates (Mbps)

	6 MHz channel (ANSI/SCTE 07 2000)			8 MHz channel (ETSI EN 300 429)[1]		
Modulation	Symbol rate (Mbaud)	Data transmission rate (Mbps)	Usable bit-rate (Mbps)	Symbol rate (Mbaud)	Data transmission rate (Mbps)	Usable bit-rate (Mbps)
16-QAM				6.952	27.808	25.491
64-QAM	5.057	30.342	26.970	6.952	41.712	38.236
256-QAM	5.361	42.884	38.811	6.952	55.616	50.981

NOTE:
Rates adjusted to produce an occupied bandwidth of 8 MHz.

CONTROL CHANNEL

In order to support interactive video services, a bi-directional control channel for set-top terminal devices must be established. This can be implemented under the existing DOCSIS standards (refer to "Cable Modem Signals" in this booklet), or the DVB-RCC (Return Channel for Cable) standard, which is defined in the ETSI publication ETS 300 800. This standard is almost identical to DAVIC "Passband Bi-directional PHY on coax" (see DAVIC 1.2 Specification, Part 8). The signal characteristics are presented in the following tables. The modulation scheme for downstream and upstream transmission is QPSK.

Downstream transmission rates and bandwidths:

	Symbol rate (MSps)	Transmission rate (Mbps)	Channel spacing (MHz)
Grade 'A' service	0.772	1.544	1
Grade 'B' service	1.544	3.088	2

Control channel for cable transmission (cont’d)

Upstream transmission rates and bandwidths:

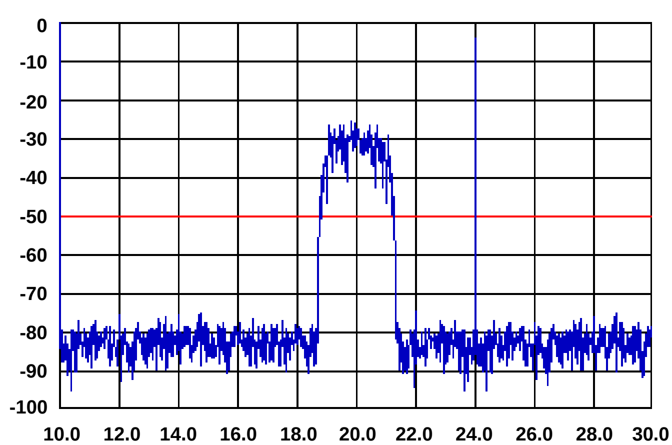
	Symbol rate (MSps)	Transmission rate (Mbps)	Channel spacing (MHz)
Grade 'A' service	0.128	0.256	0.2
Grade 'B' service	0.772	1.544	1
Grade 'C' service	1.544	3.088	2

DIGITAL SIGNALS

Measurement of signal level

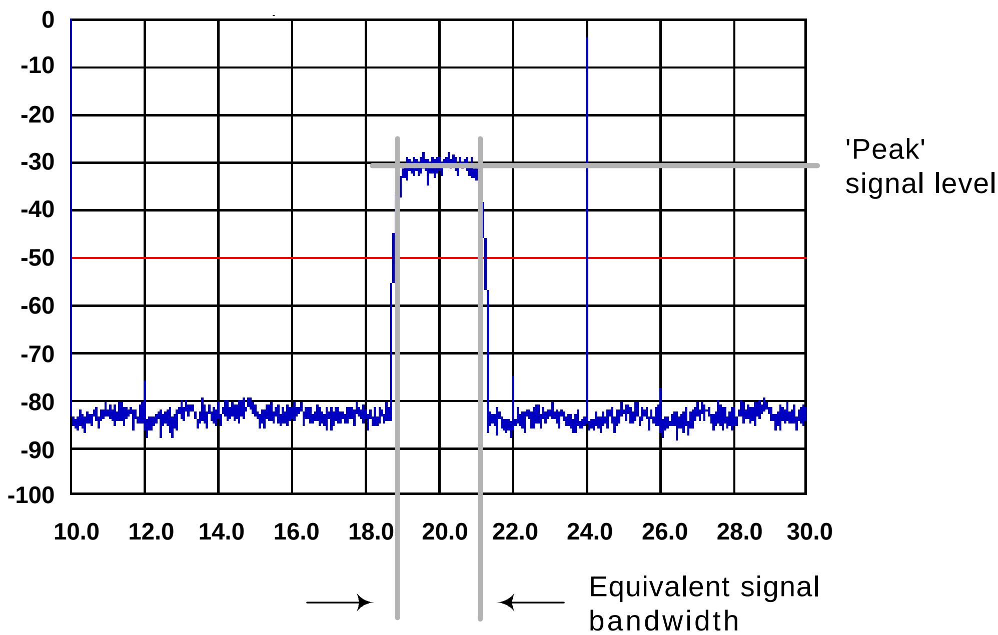
Digitally-modulated RF signals using QPSK, QAM, 8VSB and COFDM formats have characteristics similar to those of White Noise, and must be measured with the aid of a spectrum analyzer. Frequency-selective level meters will give unreliable results. Many modern spectrum analyzers designed for the Broadband industry incorporate a useful feature known as ‘channel power measurement’, which permits the direct reading of digital signal power; however, a method using a general-purpose spectrum analyzer, will be described here. A detailed description of the procedures can be found in the CENELEC standard EN 50083-7, "System Performance", upon which the following text is based.

The digital signal should be centered in the spectrum analyzer display, with the resolution bandwidth of the analyzer set to 100 kHz. (NOTE: the resolution bandwidth of a spectrum analyzer is effectively the bandwidth of the filter in the IF stage of the instrument. It is selected either by the operator or by internal optimization software. For this reason, the resolution bandwidth is often referred to as the ‘IF bandwidth’ of the analyzer). The horizontal sweep should be adjusted so that the shape of the signal is clearly visible, as shown in the following diagram:



(This diagram, and those that follow, were generated by software, and are not actual images of spectrum analyzer displays. This was done in order to improve clarity and avoid unnecessary clutter. Nevertheless, the diagram is a realistic representation of a QPSK signal, having a data rate of approximately 4.6 Mbps. The horizontal scale of the display is 2 MHz per division, and the vertical scale is 10 dB per division).

The display should then be ‘smoothed’ by switching in the video filter, which effectively averages the peak-to-valley excursions of the signal:



The average power as displayed on the analyzer should now be adjusted to arrive at a true indication of signal power. First, the reading given by the analyzer must be corrected to compensate for the characteristics of the analyzer’s IF filter and logarithmic detector: these correction factors are usually supplied by the instrument manufacturer and included with the User Guide or other relevant documentation. A correction factor of between 1.5 and 2.0 dB is typical. The result is the energy of the signal measured in the resolution bandwidth of the analyzer. This figure will be identified as P_{RBW} in the subsequent text, and the resolution bandwidth will be identified as BW_R.

Signal level measurement (cont'd)

Next, the total signal energy must be calculated, and this requires a knowledge of the bandwidth of the signal. As shown in the figure above, the analyzer's markers or graticule can be used to measure the bandwidth at points 3 dB below the average level. This is referred to as the 'equivalent signal bandwidth', and will be designated here as BW_E.

The total signal energy is then given by P_T, where

$$P_T = P_{RBW} + 10.\log\left({BW_E}/{BW_R} \right)$$

It should be noted that the measurement just described is actually a measurement of the signal power PLUS the noise power, but the noise contribution can be ignored if the level of the noise outside the digital signal channel is 15 dB below the signal level, or lower.

Measurement of signal-to-noise ratio

The signal level should be measured as described above, and the value of P_{RBW} determined. Then the noise in the same channel should be measured, using the same resolution bandwidth and video filter, by turning off the signal. This figure will be designated $N_{RBW.}$

The signal-to-noise ratio is then S/N, where

$S/N = P_{RBW} - N_{RBW}$

Again it should be noted that the noise level measured by this technique is actually the true noise PLUS the noise contribution of the spectrum analyser itself. The input to the analyzer should be disconnected and terminated. If the apparent noise level falls by more than 10 dB, then no correction to the measured value is necessary. If the reduction ('delta') is less than 10 dB, however, a correction to the measured value must be applied.

Signal level measurement (cont’d)

The following table provides a convenient listing of correction factors for a range of values of 'delta':

'delta':	1.5	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
Correction:	5.35	4.33	3.02	2.20	1.65	1.26	0.97	0.75	0.58	0.46

The correction is applied by subtracting it from the the measured value N_{RBW}.

Measured vs Calculated Bandwidth

The accuracy of the bandwidth measurement, as described above, can be verified by comparison with the calculated bandwidth of the digital signal.

The Nyquist Bandwidth of the signal (designated here as BW_N) is equal to the symbol-rate expressed in Hertz. Now the symbol-rate is the rate at which the amplitude, the phase or the frequency of the carrier (or some combination of these characteristics) is being changed, and this is not necessarily equal to the data rate.

In the more complex modulation schemes, the digital data is ‘sampled’ in blocks of bits, and the numeric value of each block is then used to determine the characteristics of the carrier.

For example, in QPSK modulation, the data is sampled in blocks of two bits. There are four possible values of each sample; 00, 01, 10 and 11, so the phase of the carrier can occupy four different states. This results in a symbol-rate which is exactly half the data rate, and hence the symbol-rate for the hypothetical QPSK signal in the figure above is obtained by dividing the data rate of 4.6 Mbps by two, giving 2.3 MSps (million symbols per second). In Hertz, this gives a value for BW_N of 2.3 MHz.

Measured vs calculated bandwidth (cont'd)

The following table gives the symbol-rate for various signal types:

Modulation Type	Symbol-rate
FSK	= bit rate
BPSK	= bit rate
QPSK	= bit rate ÷ 2
16 QAM	= bit rate ÷ 4
64 QAM	= bit rate ÷ 6
256 QAM	= bit rate ÷ 8

Assuming that the digital signal is shaped using raised-cosine filtering, and assuming that this filtering is equally distributed between transmitter and receiver, the 3 dB bandwidth of the signal, when measured by a spectrum analyzer as described above, will be approximately equal to the Nyquist bandwidth.

Recommended Levels in HFC Networks

In a typical HFC network designed for both analog and digital signals, the analog video channels will be carried in the 50 to 550 MHz range, and the remainder of the bandwidth will be allocated to digital traffic, which will consist primarily of either 64 QAM or 256 QAM modulated signals.

Scientific-Atlanta recommends that 64 QAM signals be carried at a level 10 dB below the corresponding analog video carrier level*, and 256 QAM signals at
6 dB below video carrier. (The ‘levels’ of the digital signals are as defined in the previous subsection).

Recommended levels (cont'd)

Tests have shown that the power of a 64 QAM signal will, on average, be approximately equal to that of a modulated analog signal when the digital signal is 6 dB below the carrier level of the analog signal.

* "Video carrier level" must be interpreted as the peak envelope power of the analog video signal.

Recommended Levels in the Upstream Path

To avoid laser clipping while obtaining the best CNR performance, two methods of calculating upstream signal levels at the input to a reverse optical transmitter are in common use:

1. 'Power sharing', based on known number of signals
2. 'Worst case' loading, based on NPR measurements

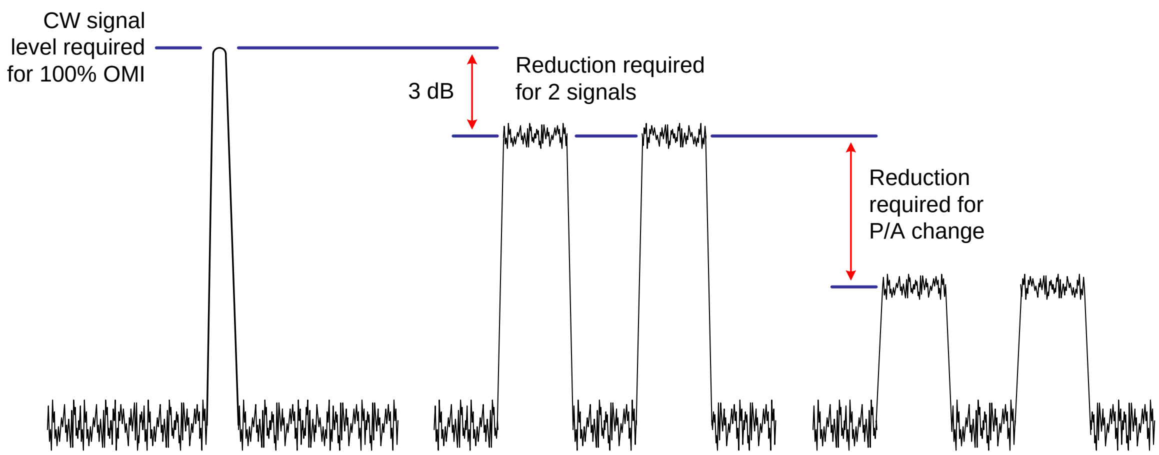
Power sharing method

If the transmitter manufacturer specifies the RF input level as a single CW tone required to produce 100% OMI, then the 'power sharing' method can be used to determine the level for a number of signals at the input. This method is also preferred when the total future traffic load of the upstream path can be predicted.

For example, if the CW level for 100% OMI is 40 dBmV, then the level for two signals should be 37 dBmV.

Unfortunately, this calculation does not take into consideration the fact that the two signals may have a significantly different peak-to-average ratio than the CW tone, whose P/A ratio is 3 dB. Therefore, if the power is measured on a spectrum analyzer, which is calibrated for true rms power, the peaks of the two signals will exceed the measured value by considerably more than 3 dB.

Recommended levels (cont'd)



P/A: peak-to-average ratio

For a digital signal, it is reasonably safe to say that the amplitude distribution of the signal is gaussian (and the more signals are added, the more true this statement becomes). There is some question, however, of the figure that should be used for P/A of a gaussian signal. A commonly-used value is 9.5 dB.
This means that the total 'back-off' for the two signals in this example should be 3 + (9.5 – 3) = 9.5 dB.

NPR method

The disadvantage of using CW tones to specify reverse transmitter performance is that a sine-wave and a complex modulated signal have completely different characteristics, as explained above. If the transmitter performance specification is based on a white (gaussian) noise measurement, this difficulty can be avoided.

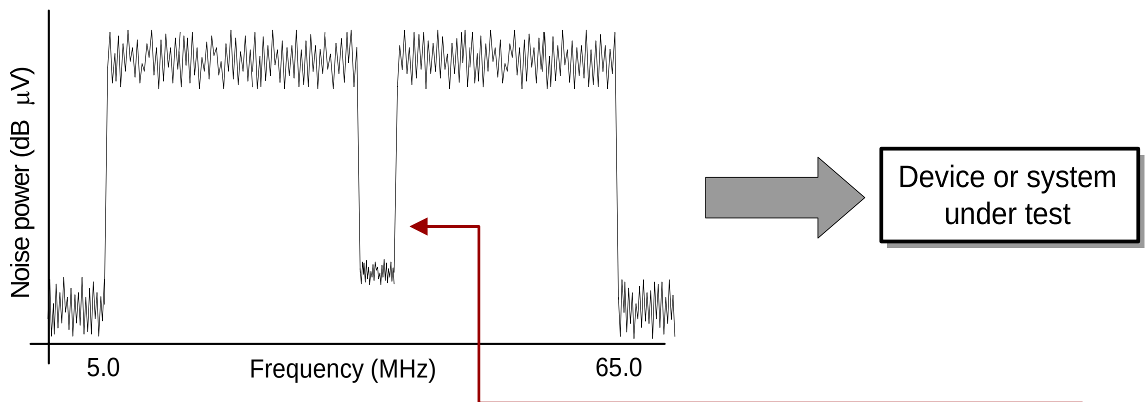
The NPR method of specifying transmitter performance is based on a <u>white noise</u> measurement, which is a better simulation of the traffic. It was used to measure the performance of multi-channel FDM telephone systems, before the adoption of digital transmission techniques.

The Noise Power Ratio (NPR) test is designed to fully load a device or system with a broad spectrum of gaussian noise, and to determine

Recommended levels (cont'd)

the degree of Intermodulation Distortion created by this noise signal, as its level is increased. Because the noise extends across the entire upstream spectrum, the test simulates the heaviest possible traffic load, and is therefore a preferred indicator of system performance when the future traffic growth is uncertain, but is expected to be high.

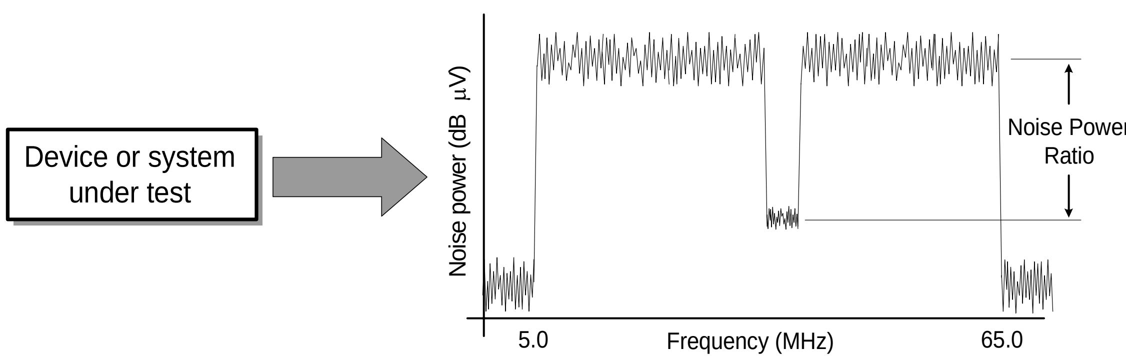
Band-limited white noise is applied to the input of the device or system:



- and a band-stop filter is used to create a 'notch' in the noise.

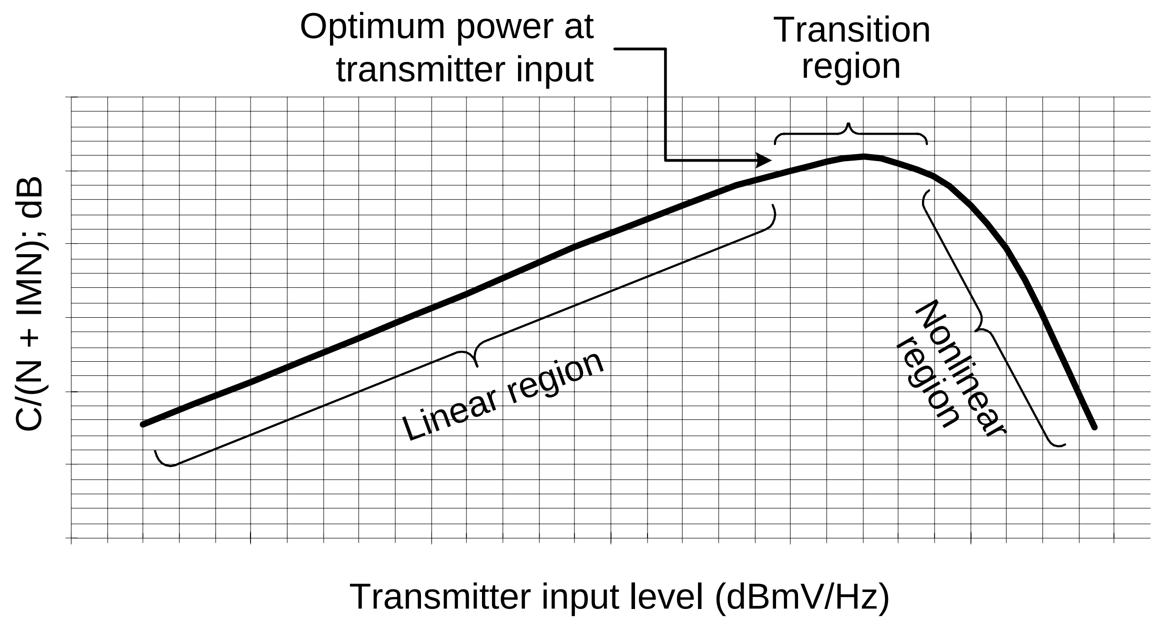
At the output of the device or system, a spectrum analyzer is used to measure the depth of the 'notch':

The 'depth' of the notch is reduced by the presence of Intermodulation products:



A plot of the depth of the notch versus the transmitter input power results in the NPR curve.

Recommended levels (cont'd)



In the linear region of the curve, the NPR increases smoothly as input power in increased. This is interpreted as a linear increase in CNR as the 'carrier' (the applied noise signal) rises above the intrinsic 'noise' of the optical system.

In the transition region, the noise signal begins to cause intermodulation distortion noise and clipping of the laser, and in the nonlinear region, further increases in the level of the applied noise result in disproportionate decreases in NPR.

To determine the optimum level of any given signal, its bandwidth must be known, and then the required level can be obtained by taking the optimum input level from the NPR curve, and normalising to the bandwidth of the desired signal.

Example: a 16QAM signal with a bandwidth of 3.2 MHz must be carried.
The optimum input level to the transmitter, as shown by the NPR curve, is -33 dBmV/Hz. The level of the 16QAM signal should therefore be:

-33 + 10.log (3,200,000) = 32.1 dBmV

Recommended levels (cont'd)

Whether the 'power sharing' or the 'NPR' method is used, the result of the calculation should be further adjusted to allow for changes in signal level at the input to the optical transmitter due to the effects of temperature on the upstream HFC plant and the uncertainties in the measurement of various plant parameters (cable lengths, etc.) A frequently-used value is 6 dB, which should be subtracted from the calculated level.

STANDARD DIGITAL INTERFACES

This section describes the digital interfaces that are frequently encountered in broadband networks and in other telecommunications systems that may exchange traffic with them.

‘Legacy’ telecommunications systems standard interfaces

NOTE: The ‘DS-x’ signals are common throughout the Americas and in some southeast Asian countries. In Europe and many other countries, the ‘E-’ signals are more common.

DS-0
Digital Signal Level 0. The telephony term for the basic channel in the digital transmission hierarchy, originally representing a single voice channel, but subsequently used also for data transmission. The data-rate is 64 kbps.

DS-1
Digital Signal Level 1. The telephony term for the 1.544 Mbps digital signal carried by a T1 facility*. Originally designed to accommodate 24 DS-0 channels, but subsequently used also as a multiplex rate for subchannels at other data-rates, and also as a ‘clear channel’ for services such as video teleconferencing.

DS-1C
Digital Signal Level 1C. 3.152 Mbps digital signal; equivalent to two DS-1 signals.

DS-2
Digital Signal Level 2. 6.312 Mbps signal, equivalent to four DS-1 signals.

DS-3
Digital Signal Level 3. 44.736 Mbps signal, equivalent to 28 DS-1 signals.

* The terms ‘T1’ and ‘DS-1’ are frequently used interchangeably. Strictly speaking, however, ‘DS-1’ refers to the electrical characteristics of the 1.544 Mbps signal, and ‘T1’ refers to the facility through which the signal travels. The term T1 was introduced by AT&T to designate a Terrestrial digital transmission system.

The ‘DS-x’ signals are also referred to as Asynchronous digital signals, to distinguish them from the later, SONET (Synchronous Optical Network) standards. In Europe, the word Plesiochronous is used, meaning ‘almost synchronous’, and the various signals in this category are referred to collectively as the Plesiochronous Digital Hierarchy, or PDH.

E-1
First Order Digital Signal, at 2.048 Mbps. It was designed to accommodate thirty 64 kbps channels but, like the DS-1 signal, has also been used as a multiplex for other lower-rate channels and as a ‘clear channel’ for services such as video teleconferencing.

E-2
Second Order Digital Signal, at 8.448 Mbps; equivalent to 4 E-1 signals.

E-3
Third Order Digital Signal, at 34.368 Mbps; equivalent to 16 E-1 signals

E-4
Fourth Order Digital Signal, at 139.264 Mbps; equivalent to 64 E-1 signals.

ISDN (Integrated Services Digital Network)

ISDN is a digital telephony system that allows voice and data to be transmitted simultaneously across a network. The voice and data signals are carried on ‘bearer’ (B) channels with a data-rate of 64 kbps. A ‘data’ (D) channels handles signaling at 16 or 64 kbps.

Basic Rate Interface (BRI)
Consists of two B channels at 64 kbps each, and one D channel at 16 kbps. This interface is considered suitable for most individual (residential) customers.

Primary Rate Interface (PRI)
In the Americas, consists of 23 B channels at 64 kbps each, and one D channel at 64 kbps. This produces an aggregate rate which is compatible with T1 transmission facilities. In Europe and other parts of the world, the PRI consists of 30 B channels and one D channel, and is therefore compatible with first-order (E-1) transmission systems. The PRI is designed for business customers.

SONET and SDH electrical interfaces

Data rate (Mbps)	Payload rate (Mbps)	SONET designation	SDH designation
51.840	50.112	STS-1	N/A
155.520	150.336	STS-3	STM-1
622.080	601.344	STS-12	STM-4
2,488.320	2,405.376	STS-48	STM-16
9,953.280	9,621.504	STS-192	STM-64
39,813.120	38,486.016	STS-768	STM-256

If the interface designation is followed by the letter ‘c’ (for example, ‘STS-3c’), this indicates a concatenated channel. That is to say, the aggregate payload for that channel is available for a single data stream.

ASI (Asynchronous Serial Interface)

The ASI is designed as a means of transferring MPEG-2 transport streams between devices in a headend or hub. It operates at a constant data-rate of 270 Mbps; however the MPEG data is 8B/10B coded, which produces a 10-bit word for each 8-bit byte in the transport steam: this coding, plus other overhead, reduces the payload to 214 Mbps.

ASI is specified in Annex ‘B’ of the CENELEC specification EN 50083-9, and is also described in the DVB Blue Book A010. The transmission medium is 75Ω coaxial cable, and the launch voltage is 800 mV ± 10% (p-p).

ANSI/SMPTE 259M

This is a family of digital interface specifications for video, which supports the following transmission rates:

Level 'A': Digital sampling of an NTSC signal at four times the chrominance subcarrier frequency ($4.f_{sc}$), resulting in a data-rate of 143 Mbps.

Level 'B': Digital sampling of a PAL signal at $4.f_{sc}$, resulting in a data-rate of 177 Mbps.

Level 'C': Digital sampling of a 4:2:2 component video signal (either 525-line/60 Hz or 625-line/50 Hz) with a data-rate of 270 MHz. This interface has essentially the same electrical characteristics as the DVB-ASI interface (270 MHz; 800 mV launch amplitude). It is also referred to as the 'D1' format, and was introduced as the standard for digital video tape recorders in the mid-1980s.

Level 'D': Digital sampling of NTSC or PAL 4:2:2 wide-screen (16 x 9 aspect ratio) video, with a data-rate of 360 Mbps.

SMPTE 259 is frequently referred to as 'SDI' (Serial Digital Interface). As mentioned above, the similarities between ASI and SDI are such that many pieces of equipment can handle both types of signal.

ANSI/SMPTE 292M

This standard defines the digital sampling of component (4:2:2) high-definition video (either 1080i or 720p), and transmission at a rate of 1.485 Gbps. An electrical (coaxial cable) interface is defined, with a transmission loss up to 20 dB, and an optical interface is also possible, for distances up to 2 km. In general, SMPTE 292M is regarded as the high-definition extension of SMPTE 259M.

ANSI/SMPTE 305M

Referred to as the Serial Digital Transport Interface (SDTI). This is not a 'physical layer' specification; rather, it defines a data communications protocol for systems which employ the physical layer specifications of SMPTE 259M (SDI).
It allows the transport of MPEG-2 packets, as well as 'raw' digital data, at a rate of either 270 Mbps or 360 Mbps. (The actual payload rates are approximately 200 and 270 Mbps, respectively).
MPEG-2 packets can be transferred at high speed, to provide a 'faster than realtime' transmission of video files.

ANSI/SMPTE 310M

This is a synchronous serial interface, designed for short distance point-to-point applications in the video broadcasting industry, such as connecting an 8VSB modulator to a transmitter. It carries a simple MPEG-2 Transport Stream at a fixed rate of either 19.39 Mbps (compatible with 8VSB transmission) or 38.78 Mbps (compatible with 16VSB transmission). If RG-59 coaxial cable is used, the range is approximately 300 ft.

CABLE DATA SIGNALS

General

This section contains information on the electrical characteristics of the downstream and upstream signals in cable data transmission systems, as defined by DOCSIS (Data Over Cable Service Interface Specifications).

Also presented in this section are the basic transmission characteristics of Element Management transponders that conform to the specifications of the Hybrid Management Sub-Layer (HMS) subcommittee of the SCTE (Society of Cable Telecommmunications Engineers).

The data were derived from the following documents:

For DOCSIS: Radio Frequency Interface Specifications,
SP-RFIv1.1-I06-001215 (December 15, 2000)

For HMS: Hybrid Fiber Coax Outside Plant Status Monitoring – Physical (PHY) Layer Specification v1.0,
ANSI/SCTE 25-1 2002 (Formerly HMS 005)

The DOCSIS specifications provide for the transmission of digital signals over broadband networks using a range of phase- and amplitude modulation schemes, the basic characteristics of which are summarized below:

QPSK (Quaternary Phase-Shift Keying)
The data to be transmitted is sampled in blocks of two bits, which can have four different values (00, 01, 10, 11). These blocks are transmitted by shifting the phase of a carrier into four possible states. Thus the signaling rate (also referred to as the Symbol Rate, and expressed in Baud) is half the transmission rate (expressed in bits per second).

Cable data signals (continued)

16-QAM (16-level Quadrature Amplitude Modulation)
The data to be transmitted is sampled in blocks of four bits, which can have 16 different values. Both the phase and the amplitude of a carrier are shifted to define each of these possible values. The signaling rate is thus one quarter of the transmission rate.

64-QAM (64-level Quadrature Amplitude Modulation)
The data to be transmitted is sampled in blocks of six bits, which can have 64 different values. Both the phase and the amplitude of a carrier are shifted to define each of these possible values.The signaling rate is thus one sixth of the transmission rate.

256-QAM (256-level Quadrature Amplitude Modulation)
The data to be transmitted is sampled in blocks of eight bits, which can have 256 different values. Both the phase and the amplitude of a carrier are shifted to define each of these possible values.The signaling rate is thus one eighth of the transmission rate.

In general, the more 'compression' that is achieved by increasing the complexity of the modulation scheme, and thus transmitting more data at a given signaling rate, the more susceptible will the signal be to noise in the transmission medium.

DOCSIS signal characteristics

The following characteristics represent a very small subset of the complete signal descriptions found in the DOCSIS specification documents. Shown here are only those characteristics that have direct relevance to the broadband system Technician or Engineer when calculating bandwidth requirements and signal levels.

DOCSIS signal characteristics (cont'd)

Downstream transmission rates and bandwidths:

	Symbol rate (MSps)	Transmission rate[1] (Mbps)	Channel spacing (MHz)
64-QAM modulation	5.056941	30.341650	6
	6.952000	41.712000	8
256-QAM modulation	5.360537	42.884296	6
	6.952000	55.616000	8

Upstream transmission rates and bandwidth:

	Symbol rate (MSps)	Transmission rate[1] (Mbps)	Channel width[2] (MHz)
QPSK modulation	0.160	0.320	0.200
	0.320	0.640	0.400
	0.640	1.280	0.800
	1.280	2.560	1.600
	2.560	5.120	3.200
16-QAM modulation	0.160	0.640	0.200
	0.320	1.280	0.400
	0.640	2.560	0.800
	1.280	5.120	1.600
	2.560	10.240	3.200

NOTES:

1. The 'transmission rate' is the rate at which binary digits are transported. The rate at which useful information is transmitted will always be less than this figure, because of the existence in the signal of overhead bits. In the downstream signal path, the overhead accounts for approximately 10% of the transmitted signal, and in the upstream signal path the figure is approximately 15%.
2. In the case of upstream signals, the 'channel width' is the –30dB bandwidth.

DOCSIS signal characteristics (cont'd)

Downstream frequency ranges and signal levels, NTSC systems with 6 MHz channel spacing:

	Output of CMTS[1]	Input to Cable Modem
Frequency	91 to 857 MHz	91 to 857 MHz
Signal level	50 to 61 dBmV	-15 to +15 dBmV

Upstream frequency ranges and signal levels, NTSC systems with 6 MHz channel spacing:

	Output of Cable Modem		Input to CMTS[1]	
Frequency	5 to 42 MHz		5 to 42 MHz	
Signal level	QPSK:	8 to 58 dBmV	160 kSps:	-16 to +14 dBmV
	16-QAM:	8 to 55 dBmV	320 kSps:	-13 to +17 dBmV
			640 kSps:	-10 to +20 dBmV
			1280 kSps:	-7 to +23 dBmV
			2560 kSps:	-4 to +26 dBmV

Downstream frequency ranges and signal levels, European systems with 7/8 MHz channel spacing:

	Output of CMTS[1]	Input to Cable Modem	
Frequency	112 to 858 MHz	112 to 858 MHz	
Signal level	110 to 121 dBµV	64-QAM:	43 to 73 dBµV
		256-QAM:	47 to 77 dBµV

DOCSIS signal characteristics (cont'd)

Upstream frequency ranges and signal levels, European systems with 7/8 MHz channel spacing:

	Output of Cable Modem		Input to CMTS[1]	
Frequency	5 to 65 MHz		5 to 65 MHz	
Signal level	QPSK:	68 to 118 dBμV	0.160 MSps:	44 to 74 dBμV
	16-QAM:	68 to 115 dBμV	0.320 MSps:	47 to 77 dBμV
			0.640 MSps:	50 to 80 dBμV
			1.280 MSps:	53 to 83 dBμV
			2.560 MSps:	56 to 86 dBμV

NOTES:

1. The CMTS is the Cable Modem Termination System, located at the Headend or a Hub, which transmits signals to, and receives signals from the Cable Modems.

HMS transponder signal characteristics

The following characteristics apply to all ‘Class 2’ and ‘Class 3’ HMS transponders, which are those (as defined in the ANSI/SCTE specification) which are purposely designed to meet the HMS specifications, as opposed to new or ‘legacy’ transponders that may be upgraded to meet the specification.

Downstream characteristics:

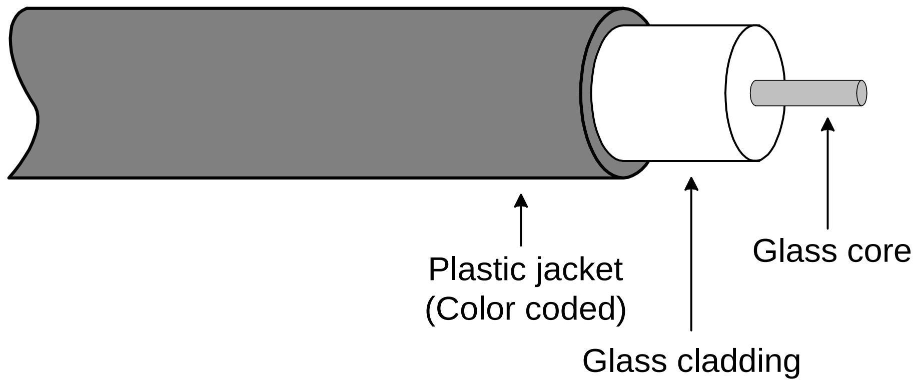
	Output of Headend transmitter	Input to transponder
Frequency	48 to 162 MHz	
Signal level	+40 to +51 dBmV	-20 to +20 dBmV
Modulation	FSK	
Bit rate	38.4 kbps	

Upstream characteristics:

	Output of transponder	Input to Headend receiver
Frequency	5 to 21 MHz	
Signal level	+25 to +45 dBmV	-20 to +20 dBmV
Modulation	FSK	
Bit rate	38.4 kbps	

FIBER CABLE CHARACTERISTICS

Mechanical Structure



A single fiber cable consists of a glass core surrounded by a concentric glass cladding; the two glasses having different refractive indeces so that light is confined to the core by total internal reflection. The protective plastic jacket is color-coded so that individual fibers can be identified in multiple-fiber bundles ('tubes').

Typical dimensions of the fiber are:

Plastic jacket:	**250µ**
Glass cladding:	**125µ**
Glass core:	**62.5µ (multimode)**
	10µ (singlemode)

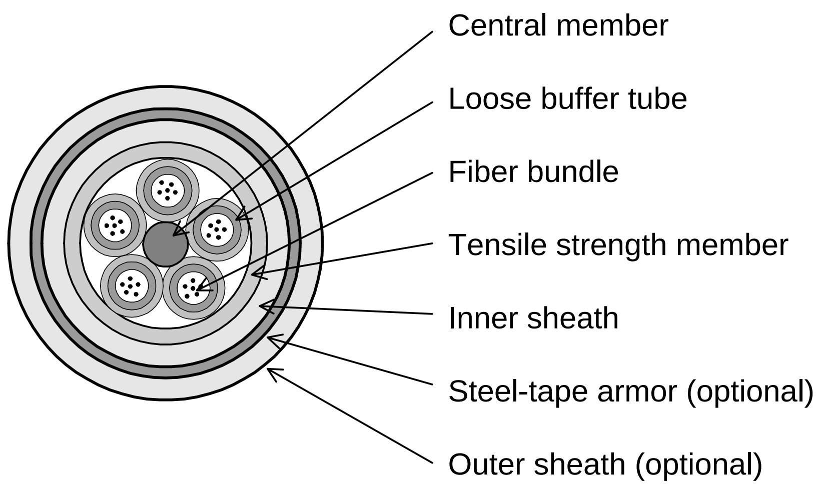
('µ' is one micrometer, or one millionth of a meter; 250µ is therefore the equivalent of one-quarter of a millimeter. It is frequently referred to as "micron")

A fiber 'pigtail' has an additional protective plastic coating with a diameter of 900µ, and a Kevlar sheath, bringing the total diameter up to approximately 2500µ (2.5mm).

Fiber cable characteristics (cont'd)

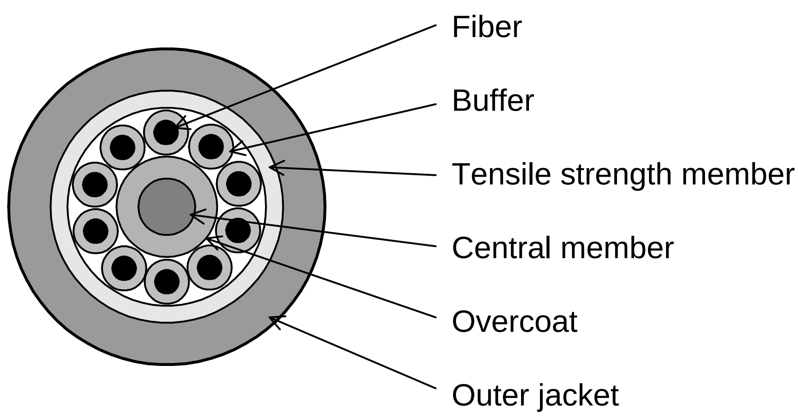
Multi-fiber cables are used when traversing any significant distance. The principal types are Loose Tube, and Tight Buffered cables, as illustrated below.
(Cable construction details and nomenclature are taken from Siecor Corporation publications)

Loose Tube Cable Cross-Section



Loose tube cables contain hollow buffer tubes with one or more fibers inside each tube.

Tight Buffered Cable Cross-Section



Tight buffered cables have a 900 micrometer (μ) diameter plastic coating applied directly to each fiber.

Fiber cable characteristics (cont'd)

In general, loose-tube cables are used in outdoor installations, where the isolation of the individual fibers from external stress maximizes the cable life. On the other hand, tight buffered cables have their main application in indoor environments. These cables are typically more sensitive to adverse temperatures and external forces than the loose-tube design, but are desirable because of their increased flexibility, smaller bend radius, and easier handling characteristics. (Applications information taken from Siecor Corporation publications)

Color Coding of Fibers

For multi-fiber cables, a color coding scheme is used to distinguish individual fibers. In loose tube construction, up to 12 fibers can be placed in each tube, and they are coded as follows (in accordance with EIA/TIA-598; "Color Coding of Fiber Optic Cables"):

1. Blue	7. Red
2. Orange	8. Black
3. Green	9. Yellow
4. Brown	10. Violet
5. Slate	11. Rose
6. White	12. Aqua

Buffer tubes containing fibers are also color coded in accordance with the same EIA/TIA standard:

1. Blue	7. Red
2. Orange	8. Black
3. Green	9. Yellow
4. Brown	10. Violet
5. Slate	11. Rose
6. White	12. Aqua

Loss Characteristics of Fiber Optic Cables

The information contained in this section, addresses only the transmission of linearly-modulated optical signals at 1310 nm and 1550 nm through singlemode fibers. In designing optical links for Broadband networks, Scientific-Atlanta uses conservative estimates of fiber performance, and the contribution of associated optical components. Thus the information which follows should be used when specific details of actual plant performance are unknown: in many cases the true performance of an optical link will be better than that indicated by the conservative figures given here.

Loss Characteristics of Fiber Optic Cables (cont'd)

Fiber loss:	**0.35 dB per km** (0.56 dB/mile) at 1310 nm*
	0.25 dB per km (0.40 dB/mile) at 1550 nm
Splice loss:	**0.05 dB per km** (fusion splices)
	0.15 dB for each mechanical splice
Connector loss:	**0.25 dB** for each super FC-PC connector set
Sag & storage:	**Add 4%** to fiber length

* For standard CATV dual-window fiber.

Loss Characteristics of Fiber Optic Cables (cont'd)

The following tables use the figures given above to compute optical losses for a range of path lengths.

1310 nm

Path length mi	Path length km	Fiber loss	with splices	with connectors	Path length mi	Path length km	Fiber loss	with splices	with connectors
1	1.6	0.56	0.64	1.14	13	20.8	7.28	8.32	8.82
2	3.2	1.12	1.28	1.78	14	22.4	7.84	8.96	9.46
3	4.8	1.68	1.92	2.42	15	24.0	8.40	9.60	10.10
4	6.4	2.24	2.56	3.06	16	25.6	8.96	10.24	10.74
5	8.0	2.80	3.20	3.70	17	27.2	9.52	10.88	11.38
6	9.6	3.36	3.84	4.34	18	28.8	10.08	11.52	12.02
7	11.2	3.92	4.48	4.98	19	30.4	10.64	12.16	12.66
8	12.8	4.48	5.12	5.62	20	32.0	11.20	12.80	13.30
9	14.4	5.04	5.76	6.26	21	33.6	11.76	13.44	13.94
10	16.0	5.60	6.40	6.90	22	35.2	12.32	14.08	14.58
11	17.6	6.16	7.04	7.54	23	36.8	12.88	14.72	15.22
12	19.2	6.72	7.68	8.18	24	38.4	13.44	15.36	15.86

1550 nm

Path length mi	Path length km	Fiber loss	with splices	with connectors	Path length mi	Path length km	Fiber loss	with splices	with connectors
1	1.6	0.40	0.48	0.98	13	20.8	5.20	6.24	6.74
2	3.2	0.80	0.96	1.46	14	22.4	5.60	6.72	7.22
3	4.8	1.20	1.44	1.94	15	24.0	6.00	7.20	7.70
4	6.4	1.60	1.92	2.42	16	25.6	6.40	7.68	8.18
5	8.0	2.00	2.40	2.90	17	27.2	6.80	8.16	8.66
6	9.6	2.40	2.88	3.38	18	28.8	7.20	8.64	9.14
7	11.2	2.80	3.36	3.86	19	30.4	7.60	9.12	9.62
8	12.8	3.20	3.84	4.34	20	32.0	8.00	9.60	10.10
9	14.4	3.60	4.32	4.82	21	33.6	8.40	10.08	10.58
10	16.0	4.00	4.80	5.30	22	35.2	8.80	10.56	11.06
11	17.6	4.40	5.28	5.78	23	36.8	9.20	11.04	11.54
12	19.2	4.80	5.76	6.26	24	38.4	9.60	11.52	12.02

OPTICAL PASSIVES

Singlemode Multiband Couplers and Splitters

The data in this section represent the specifications of the fused couplers and splitters available from Scientific-Atlanta. Two-way splitters/couplers are available either unconnectorized, or in LGX-compatible modules.

Fused coupler/splitter optical specifications:

		Maximum insertion loss (dB)*	
Configuration	**Split ratio**	**Through**	**Tap**
1 : 2	50 / 50	4.00	4.00
	55 / 45	3.60	4.50
	60 / 40	3.20	5.00
	65 / 35	2.75	5.60
	70 / 30	2.55	6.30
	75 / 25	2.15	7.00
	80 / 20	1.80	8.10
	85 / 15	1.50	9.30
	90 / 10	1.30	11.25
	95 / 05	1.05	14.35
1 : 2 dual	50 / 50	4.00	4.00
2 : 2	Even	4.00	4.00
2 : 4	Even	7.70	7.70
1 : 3	Even	6.3 / 6.3 / 6.3	
	35 / 35 / 30	5.3 / 5.3 / 5.9**	
	40 / 30 / 30	4.6 / 5.9 / 5.9**	
	50 / 25 / 25	3.6 / 6.7 / 6.7**	
	40 / 40 / 20	4.9 / 4.9 / 7.8**	
	60 / 20 / 20	2.8 / 7.7 / 7.7**	
1 : 4	Even	7.60	
1 : 5	Even	8.95	
1 : 6	Even	9.90	
1 : 7	Even	10.90	
1 : 8	Even	11.20	
1 : 10	Even	13.30	
1 : 12	Even	13.50	
1 : 16	Even	14.90	

* Includes connector losses.
± 20nm, -20 to +65˚ C

** Typical insertion loss

The <u>theoretical</u> loss in decibels through one ‘leg’ of an optical coupler can be calculated from the numerical value of the loss as follows:

Loss through port ‘A’ (in dB) = $10 * \log(F_A)$

Where F_A = numerical loss, expressed as a fraction (for example; 35% becomes 0.35)

The actual optical loss through a directional coupler will be higher than the value obtained from this formula, since factors such as backscatter, polarization effects, temperature/humidity changes, aging, wavelength dependence, etc. add to the loss.

DWDM multiplexers and demultiplexers

The following table contains the performance specifications for single- and multiple-channel DWDM multiplexers and demultiplexers in the Prisma® and LaserLink® product-lines from Scientific-Atlanta. These devices are available with channel spacings of 100 and 200 GHz, in accordance with the ITU wavelength grid.

Mux/demux optical specifications:

	1 ch. OADM	4 ch	8 ch	12 ch	16 ch	20 ch
Insertion loss, dB (max): 200 GHz*	n/a					
Prisma						
Multiplexer		2.3	3.4	4.8	4.8	n/a
Demultiplexer		2.3	3.4	4.8	4.8	n/a
Combined		4.0	4.9	6.4	7.4	n/a
LaserLink						
Mux/demux		2.3	3.0	n/a	4.0	4.0
Insertion loss, dB (max): 100 GHz Mux/demux	<1.1 (add/drop) < 0.8 (other)	n/a	3.2	n/a	n/a	n/a
Isolation, dB (max)	> 30 (add/drop) > 12 (other)	> 30 (adjacent channels > 40 (non-adjacent channels)				

* Includes connector losses

CWDM multiplexers and demultiplexers

The following table contains the performance specifications for single- and multiple-channel DWDM multiplexers and demultiplexers in the Prisma® product-line from Scientific-Atlanta. These devices are available with channel spacings of 20nm, at wavelengths from 1430 to 1610nm, in accordance with the ITU wavelength grid.

Mux/demux optical specifications:

Center wavelength (nm)	1430, 1450, 1470, 1490, 1510 1530, 1550, 1570, 1590, 1610			
Configuration:	**1 ch. OADM**	**4 ch**	**8 ch**	**12 ch**
Insertion loss, dB*	< 1.2 (add/drop) < 0.8 (other)	2.2	3.0	3.3
Isolation, dB	> 30 (add/drop) > 12 (other)	> 30 (adjacent channels > 40 (non-adjacent channels)		

* Includes connector losses

Common specifications:

Passband	13 at -0.5 dB	nm
Passband ripple	< 0.5	dB
Uniformity	< 1.0	dB
Polarization Dependent Loss (PDL)	< 0.25	dB
Polarization Mode Dispersion (PMD)	< 0.2	ps
Thermal stability	< 0.008	nm/˚C
Directivity	> 55	dB
Optical return loss	> 50	dB

BWDM multiplexers and demultiplexers

Scientific-Atlanta Prisma® Band Wave Division Multiplexing optical devices are used to multiplex and demultiplex blocks of wavelengths with low loss. Versions are available for combining or splitting signals at 1310/CWDM and 1310/1550 nm wavelengths, and within the 'C' band (1530 to 1565 nm).

Mux/demux optical specifications:

Type	Port	Operating wavelength (nm)	Max insertion loss (dB)*	Min isolation (dB)
1310 / CWDM	1310	1280 - 1340	1.2	20
	CWDM	1420 - 1620	0.8	12
1310 / 1550	1310	1260 - 1360	1.3	40
	1550	1500 - 1600	1.1	40
Red / blue	Blue	1529.5 – 1542.5	1.5	10
	Red	1548.5 – 1561.5	1.3	10
Red/blue/purple	Purple	1543.6 – 1546.2		
	Red/blue	1528.5 – 1541.7 1549.0 – 1561.9	0.7	12
Dual, with band 1 access	Band 1	1558.8 – 1564.9	1.2	25
	Bands 2-5	1530.1 – 1557.6	0.8	12
Dual, with band 2 access	Band 2	1551.5 – 1557.6	1.2	25
	Band 1 Bands 3-5	1558.8 – 1546.9 1530.1 – 1550.3	0.8	12
Dual, with band 3 access	Band 3	1544.3 – 1550.3	1.2	25
	Bands 1-2 Bands 4-5	1530.1 – 1543.1 1551.5 – 1565.0	0.8	12
Dual, with band 4 access	Band 4	1537.2 – 1543.1	1.2	25
	Bands 1-3 Band 5	1544.3 – 1564.9 1530.1 – 1536.0	0.8	12
Dual, with band 5 access	Band 5	1530.1 – 1536.0	1.2	25
	Bands 1-4	1537.2 – 1564.9	0.8	12
Five-band	Band 1	1558.7 – 1565.0	2.2	25
	Band 2	1551.5 – 1557.6	2.2	25
	Band 3	1544.3 – 1550.4	2.2	25
	Band 4	1537.2 – 1543.2	2.2	25
	Band 5	1530.0 – 1536.1	2.2	13

* Includes connector losses

BWDM mux/demux (continued)

Common specifications:

Directivity	≥ 50	dB
Optical return loss	≥ 50	dB
Optical power	250 max	mW

Dispersion Compensation Modules

The effects of chromatic dispersion in optical fiber can be compensated by using Dispersion Compensation Modules (DCMs) placed at intervals along the fiber route. Scientific-Atlanta Prisma® DCMs are available in a range of models, corresponding to different lengths of singlemode fiber. Both standard and low-loss versions can be specified.

DCM optical specifications (standard version):

Type	Dispersion at 1550 nm (ps per nm)	Maximum loss at 1550 nm[C] (dB)	RDS[A] (nm^{-1})	Max. PMD[B] (ps)
DCM 20	-340 ± 3%	3.5	0.0023 ± 20%	0.45
DCM 30	-510 ± 3%	4.4	0.0023 ± 20%	0.55
DCM 40	-680 ± 3%	5.2	0.0023 ± 20%	0.63
DCM 50	-850 ± 3%	6.1	0.0023 ± 20%	0.70
DCM 60	-1020 ± 3%	7.0	0.0023 ± 20%	0.77
DCM 70	-1190 ± 3%	7.9	0.0023 ± 20%	0.83
DCM 80	-1360 ± 3%	8.9	0.0023 ± 20%	0.89

Notes

A. RDS: Relative Dispersion Slope
B. PMD: Polarization Mode Dispersion
C. Includes connector losses

DCM optical specifications (low-loss version):

Type	Dispersion at 1550 nm (ps per nm)	Maximum loss at 1550 nm (dB)	RDS (nm^{-1})	Max. PMD (ps)
DCM 20	-340 ± 3%	1.9	0.0015 – 0.0055	0.54
DCM 30	-510 ± 3%	2.4	0.0015 – 0.0056	0.66
DCM 40	-680 ± 3%	2.8	0.0015 – 0.0057	0.76
DCM 50	-850 ± 3%	3.3	0.0015 – 0.0058	0.85
DCM 60	-1020 ± 3%	3.7	0.0015 – 0.0059	0.93
DCM 70	-1190 ± 3%	4.2	0.0015 – 0.0060	1.01
DCM 80	-1360 ± 3%	4.6	0.0015 – 0.0061	1.08

Each DCM is designed to compensate for a specific amount of dispersion. For example, the DCM 20 is used to compensate for 20 km of dispersion.

OPTICAL WAVELENGTH DESIGNATIONS

The range of wavelengths available for optical communication via singlemode fiber today is divided into five bands, as shown in figure 14-1. The 'O' (Original) and 'C' (Conventional) bands are the most frequently used, and are loosely referred to as the 1310nm and 1550nm bands, respectively.

Complete designations are as follows:

O-band:	Original
E-band:	Extended
S-band:	Short
C-band:	Conventional
L-band:	Long

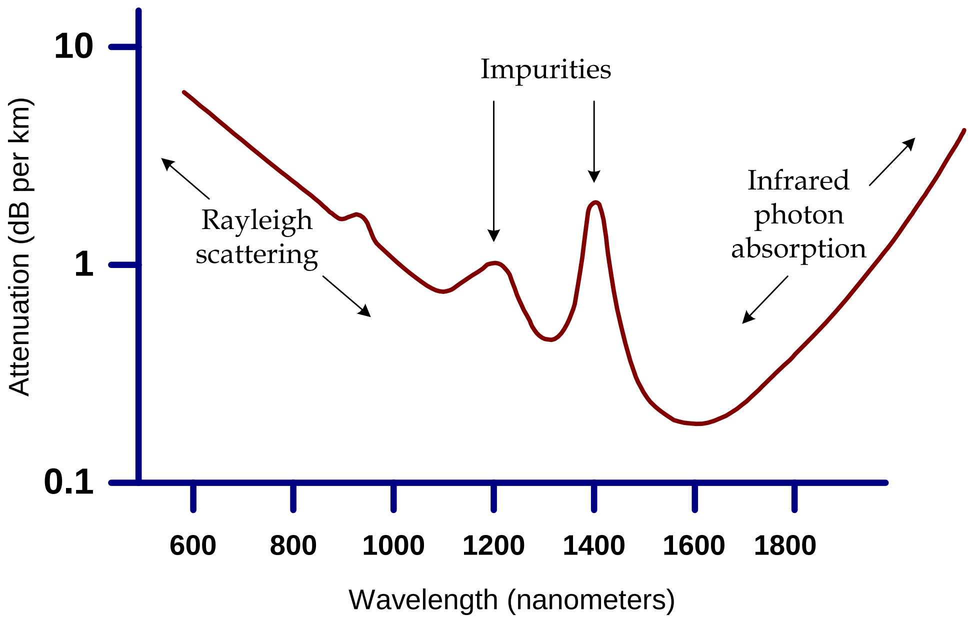
The C- and L-bands are divided into 'red' and 'blue' sections, as follows:

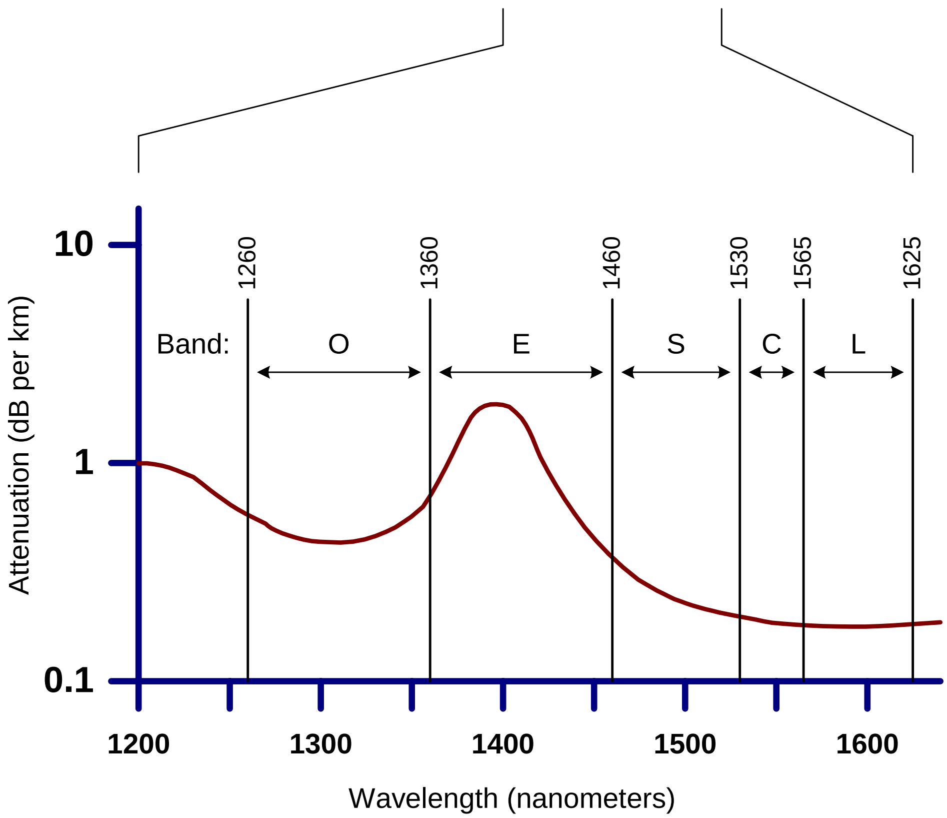
C-band, blue:	1525 to 1544nm
C-band, red:	1547 to 1565nm
L-band, blue:	1560 to 1584nm
L-band, red:	1588 to 1620nm

Optical channels for DWDM systems are defined by ITU (International Telecommunications Union) in their standard G.692 ("Optical Interfaces for Multichannel Systems with Optical Amplifiers"). The channel designations are based on the frequency of the optical signal, given in TeraHertz (THz, or 10^{12} Hertz).

In table 14-1, the most commonly used ITU-grid channels are given. (The standard includes channels in large sections of the L- and S-bands, but they are seldom encountered in the broadband industry). It should be noted that although most manufacturers supply optical components that operate at increments of either 100 or 200 GHz, a 50 GHz spacing is also possible. The table also shows the channels offered in the Scientific-Atlanta digital and analog optical transmission product-lines.

Optical wavelength designations (cont'd)





Note: the attenuation curve represents the characteristics of SMF-28 fiber, which is most commonly encountered in existing broadband networks

Figure 14-1: Fiberoptic transmission bands

Optical wavelength designations (cont'd)

Channel No.	Frequency (THz)	Wavelength (nm)	Prisma IP	Prisma GbE	iLynx	Prisma DT	bdr™ installed in node	bdr™ installed in chassis	Proteus node digital reverse	Laser Link digital reverse	LaserLink upstream	LaserLink downstream (QAM)	Prisma II upstream	Prisma II downstream (QAM)
10	191.0	1569.59												
11	191.1	1568.77												
12	191.2	1567.95						X						
13	191.3	1567.13	X				X	X					X	X
14	191.4	1566.31						X						
15	191.5	1565.50	X				X	X					X	X
16	191.6	1564.68						X						
17	191.7	1563.86	X	X			X	X					X	X
18	191.8	1563.05						X						
19	191.9	1562.23	X	X			X	X					X	X
20	192.0	1561.42						X						
21	192.1	1560.61	X	X	X	X	X	X	X	X	X	X	X	X
22	192.2	1559.79						X						
23	192.3	1558.98	X	X	X	X	X	X	X	X	X	X	X	X
24	192.4	1558.17						X						
25	192.5	1557.36	X	X	X	X	X	X	X	X	X	X	X	X
26	192.6	1556.55						X						
27	192.7	1555.75	X	X	X	X	X	X	X	X	X	X	X	X
28	192.8	1554.94						X						
29	192.9	1554.13	X	X	X	X	X	X	X	X	X	X	X	X
30	193.0	1553.33						X						
31	193.1	1552.52	X	X	X	X	X	X	X	X	X	X	X	X
32	193.2	1551.72						X						
33	193.3	1550.92	X	X	X	X	X	X	X	X	X	X	X	X
34	193.4	1550.12						X						
35	193.5	1549.32	X	X	X	X	X	X	X	X	X	X	X	X
36	193.6	1548.51						X						

Table 14-1: ITU-grid DWDM channels

Optical wavelength designations (cont'd)

Channel No.	Frequency (THz)	Wavelength (nm)	Prisma IP	Prisma GbE	iLynx	Prisma DT	bdr™ installed in node	bdr™ installed in chassis	Proteus node digital reverse	Laser Link digital reverse	LaserLink upstream	LaserLink downstream (QAM)	Prisma II upstream	Prisma II downstream (QAM)
37	193.7	1547.72	X	X	X	X	X	X	X	X	X	X	X	X
38	193.8	1546.92						X						
39	193.9	1546.12	X	X		X	X	X	X	X	X	X	X	X
40	194.0	1545.32						X						
41	194.1	1544.53	X	X		X	X	X	X	X	X	X	X	X
42	194.2	1543.73						X						
43	194.3	1542.94	X	X		X	X	X	X	X	X	X	X	X
44	194.4	1542.14						X						
45	194.5	1541.35	X	X		X	X	X	X	X	X	X	X	X
46	194.6	1540.56						X						
47	194.7	1539.77	X	X		X	X	X	X	X	X	X	X	X
48	194.8	1538.98						X						
49	194.9	1538.19	X	X		X	X	X	X	X	X	X	X	X
50	195.0	1537.40						X						
51	195.1	1536.61	X	X		X	X	X	X	X	X	X	X	X
52	195.2	1535.82						X						
53	195.3	1535.04	X	X		X	X	X	X	X	X	X	X	X
54	195.4	1534.25						X						
55	195.5	1533.47	X	X		X	X	X	X	X	X	X	X	X
56	195.6	1532.68						X						
57	195.7	1531.90	X	X		X	X	X	X	X	X	X	X	X
58	195.8	1531.12						X						
59	195.9	1530.33	X	X			X	X	X	X	X	X	X	X
60	196.0	1529.55												
61	196.1	1528.77	X											
62	196.2	1527.99												
63	196.3	1527.22												

Table 14-1 (continued): ITU-grid DWDM channels

Optical wavelength designations (cont'd)

The frequency and the wavelength of an optical signal are related by the approximate formulas:

$$\text{Wavelength (in nm)} = \frac{299800}{\text{Frequency}(\text{in THz})}$$

$$\text{Frequency (in THz)} = \frac{299800}{\text{Wavelength}(\text{in nm})}$$

It may also be noted that the channel number can be derived from the frequency by taking the 'units' and the 'tenths' from the frequency in TeraHertz. For example:

Channel 59 is at a frequency of 19[5].[9] THz, and

Channel 37 is at a frequency of 19[3].[7] THz

Optical channels for CWDM systems are defined by ITU in their standard G.694.2 ("Spectral Grids for WDM Applications: CWDM Wavelength Grid"). The channels are spaced at intervals of 20nm, and are listed in Table 14-2, which also shows the channels offered in the Scientific-Atlanta digital and analog optical transmission product-lines.

Optical wavelength designations (cont'd)

Channel No.	Wavelength (nm)	Prisma IP	Prisma GbE	bdr™ installed in node	bdr™ installed in chassis	Model 9007x 'Compact' Node	FiberLinX Media Converters
1	1610	X	X	X	X	X	X
2	1590	X	X	X	X	X	X
3	1570	X	X	X	X	X	X
4	1550	X	X	X	X	X	X
5	1530	X	X	X	X	X	X
6	1510	X	X	X	X	X	X
7	1490	X	X	X	X	X	X
8	1470	X	X	X	X	X	X
9	1450						X
10	1430						X
11	1410						
12	1390						
13	1370						
14	1350						
15	1330					X	
16	1310					X	
17	1290					X	
18	1270					X	

Table 14-2: ITU-grid CWDM channels

OPTICAL LINK PERFORMANCE

Carrier-to-Noise Ratio

This section provides formulas for the calculation of Carrier-to-Noise Ratio (CNR) in optical systems based on DFB lasers. The contribution of optical amplifiers (EDFAs) is given, but of course would be excluded in 1310nm systems. Worked examples are also presented.

1. Laser Noise

The relative intensity noise (RIN) produced by a laser is caused by the spontaneous emission of photons, and results in the production of non-coherent light.

The CNR due to laser RIN is given by the formula:

$$CNR_{RIN} = \frac{m^2}{2.B.(RIN)}$$

where
m is the single-channel modulation index, and
B is the noise measurement bandwidth (4 MHz for NTSC systems)

In decibel notation,

CNR_{RIN} = 20.log(m) – 10.log(2.B) – (RIN)

With a typical loading of 78 NTSC channels and 33 QAM signals, the per-channel OMI will be 3.58% (=0.0358). Therefore,

CNR_{RIN} = 20.log(0.0358) – 10.log(8.10^6) – (RIN)

and for a typical laser the RIN is –160 dB/Hz, therefore

CNR_{RIN} = -97.95 + 160 = 62.05 dB

2. EDFA Noise

Noise in an optical amplifier is also produced by the spontaneous emission of photons, and is referred to as Amplified Spontaneous Emission (ASE).

The CNR due to ASE is given by the formula:

$$CNR_{EDFA} = \frac{SNR_{IN}.m^2}{2.B.F}$$

where
SNR_{IN} is the amplifier input Signal-to-Noise Ratio, and
F is the amplifier Noise Factor.

The input signal-to-noise ratio is given by: $SNR = \dfrac{\lambda.P_{IN}}{2.h.c}$

where
λ is the laser wavelength in meters,
P_{IN} is the EDFA optical input power in watts,
h is Planck's constant (6.63×10^{-34} J.s), and
c is the velocity of light (3×10^{8} m.s^{-1})

Therefore $SNR_{IN} = \dfrac{(1.55 \times 10^{-6}).P_{IN}}{2.(6.63 \times 10^{-34}).(3 \times 10^{8})} = (3.896 \times 10^{18}).P_{IN}$

If the bandwidth (B) is 4 MHz, then $CNR_{EDFA} = \dfrac{(4.87 \times 10^{11}).m^2.P_{IN}}{F}$

The EDFA Noise Factor (F) is obtained from the Noise Figure (NF) by the identity NF = 10.log(F). Then, converting to decibel notation, and bearing in mind that 'dBm' is referenced to milliwatts,

$CNR_{EDFA} = 116.87 + 20.\log(m) + P_{IN} – 10.\log(10^3) – NF$

A value of the Noise Figure for a typical EDFA is 5.5 dB, with an optical input power of +5 dBm, and with m = 0.0358,

CNR_{EDFA} = 116.87 – 28.9 + 5 – 30 – 5.5 = <u>57.47 dB</u>

3. Receiver Noise

Step 1: determination of receiver responsivity

The responsivity, ρ, of a receiver in Amperes per Watt is given by

$$\rho = \frac{\eta . q . \lambda}{h.c}$$

where
η is the quantum efficiency of the detector,
q is the electron charge in coulombs,
λ is the wavelength in meters,
h is Planck's constant (6.63×10^{-34} J.s), and
c is the velocity of light (3×10^{8} $m.s^{-1}$)

Assuming a typical value for η of 0.8, the responsivity will be

$$\rho = \frac{0.8 \times (1.60 \times 10^{-19}).(1.55 \times 10^{-6})}{(6.63 \times 10^{-34}).(3 \times 10^{8})} = \underline{1.0 \text{ A.W}^{-1}}$$

Step 2: determination of receiver Shot Noise

The receiver Shot Noise is due to the random occurrence of photons and electrons and is given by:

$$CNR_{shot} = \frac{m^2 . \rho . P_{IN}}{4 . q . B}$$

where ρ is the receiver responsivity, as determined in Step 1, and m, P_{IN}, q, and B are as previously defined.

$$\text{Then } CNR_{shot} = \frac{m^2 .(1.0). P_{IN}}{4.(1.6 \times 10^{-19}).(4 \times 10^{6})} = (3.91 \times 10^{11}).m^2 . P_{IN}$$

Receiver noise (cont'd)

Expressed in decibel notation, and recalling that 'dBm' is referenced to milliwatts,

CNR_{shot} = 115.92 + 20.log(m) + P_{IN} – 10.log(10^3)

For a typical input power of 0 dBm, and a per-channel modulation index of 0.0358,

CNR_{shot} = 57.0 dB

Step 3: determination of receiver Thermal Noise

The receiver Thermal Noise is generated in the resistor and amplifier following the detector, and is given by:

$$CNR_{therm} = \frac{(m.\rho.P_{IN})^2}{2.i_n^{\,2}.B}$$

where i_n^2 is the 'thermal noise equivalent current' of the amplifier, and m, ρ, P_{IN}, and B are as previously defined.

The thermal noise in the amplifier immediately following the photodetector is characterized by a quantity called the 'thermal noise equivalent current'; it has the dimensions of picoAmperes per √Hz, or $pA.Hz^{-½}$

In the formula given above, however, the current is assumed to be expressed in Amperes, and so a factor of 10^{-12} must be included. A typical value for a transimpedance amplifier with a GaAsFET input stage is 7.0 $pA.Hz^{-½}$

Using the values of ρ and B from previous pages,

$$CNR_{therm} = \frac{m^2.(1.0)^2.P_{IN}^{\,2}}{2.(7.0 \times 10^{-12})^2.(4 \times 10^6)} = (2.55 \times 10^{15}).m^2.P_{IN}^{\,2}$$

Receiver noise (cont'd)

If P_{IN} is expressed in dBm, then for P_{IN}^2 a correction factor of 10^{-6} must be included. If the modulation index is 0.0358, and the optical input power is 0 dBm, then, in decibel notation:

$$CNR_{therm} = 10.\log(2.55 \times 10^{15}) + 20.\log(0.0358) + 0 - 10.\log(10^{6})$$

$$= \underline{65.14 \text{ dB}}$$

4. Overall Noise

The CNR for a complete optical link can then be calculated by combining the figures for the transmitter, the optical amplifier and the receiver:

$$CNR_{total} = 10.\log\left[10^{-\left(\frac{CNR_{RIN}}{10}\right)} + 10^{-\left(\frac{CNR_{EDFA}}{10}\right)} + 10^{-\left(\frac{CNR_{shot}}{10}\right)} + 10^{-\left(\frac{CNR_{therm}}{10}\right)}\right]$$

Using the examples given above, the overall CNR would be:

$$10.\log\left(10^{-6.205} + 10^{-5.747} + 10^{-5.700} + 10^{-6.361}\right) = 10.\log\left(4.84 \times 10^{-6}\right)$$

$$= \underline{53.15 \text{ dB}}$$

5. Optical Modulation Index

Optical Modulation Index (OMI) is a measure of the degree of modulation of the optical carrier by an RF signal. It is defined mathematically as the ratio of the peak RF modulating current to the average modulating current:

$$\boxed{OMI = \frac{I_{rf,peak}}{I_{mod}}}$$

Optical modulation index (cont'd)

The RF modulating current, $I_{rf,peak}$, can be written as:

$$I_{rf,peak} = \frac{V_{rf,peak}}{75\Omega} = \frac{\sqrt{2}.V_{rf,rms}.k}{75\Omega}$$

where $V_{rf,rms}$ is the input to the laser matching circuit, and k is the laser match factor. The average laser drive current, I_{mod}, can be written as:

$$I_{mod} = \frac{P_{opt}}{\varepsilon}$$

where P_{opt} is the average output optical power, and ε is the laser slope efficiency. Therefore the OMI, m, can be written as:

$$m = \frac{\sqrt{2}.V_{rf,rms}.k.\varepsilon}{P_{opt}.75\Omega}$$

The OMI is directly proportional to laser input voltage, and therefore if the input voltage changes by a certain ratio, the OMI will change by the same ratio:

$$m \;\alpha\; V_{rf,rms}, \text{ therefore } \frac{m_1}{m_2} = \frac{V_1}{V_2}$$

If V_1 and V_2 are expressed in terms of dBmV, then

$$\frac{m_1}{m_2} = \frac{10^{\left(V_1/20\right)}}{10^{\left(V_2/20\right)}} \quad \text{or} \quad \frac{m_1}{m_2} = 10^{\left(\frac{V_1 - V_2}{20}\right)}$$

Conversely, a change in OMI will require a change in drive voltage:

$$V_1 - V_2 = 20.\log\left\{\frac{m_1}{m_2}\right\}$$

Optical modulation index (cont'd)

The OMI referred to in the preceding text is the per channel OMI; another useful parameter is the composite rms OMI, denoted by the symbol μ. The approximate value of μ is given by:

$$\mu = m.\sqrt{\frac{N}{2}}$$

where N is the number of channels. This approximation is only valid when N is substantially greater than 10 and when the channels are of equal amplitude. For a smaller number of channels, the composite OMI is additive on a peak voltage basis, for the worst case.

BROADBAND PARAMETERS

The Decibel

The decibel (dB) provides a means of representing large power ratios as manageable, small numbers, and allows the overall gains and losses in a module or a network to be calculated by addition and subtraction, rather than by multiplication and division.

The original unit was the Bel (named after Alexander Graham Bell), and the decibel is one-tenth of a Bel. Thus the ratio of two power levels is calculated as follows:

Ratio of power P_1 to power P_2, in dB:

$$= 10 * \log\left(\frac{P_1}{P_2}\right)$$

If voltage, rather than power levels are known, and provided that the impedance is constant, the power ratio can be calculated as follows:

Ratio of power produced by voltage V_1 to power produced by voltage V_2, in dB:

$$= 20 * \log\left(\frac{V_1}{V_2}\right)$$

Power and Voltage Conversion

dBmV

'0 dBmV' defines the power produced when a voltage of 1 mV (rms) is applied across a defined impedance (75Ω in the broadband industry).

Therefore a measurement of 'x dBmV' in a defined impedance indicates that the power being measured is x dB greater than that produced when a voltage of 1 mV is applied across the same impedance.

To convert x dBmV to millivolts:

$$\text{Signal level in millivolts} = 10^{\left(\frac{x}{20}\right)}$$

dBμV

Similarly, a measurement of ‘x dBμV’ in a defined impedance indicates that the power being measured is x dB greater than that produced when a voltage of 1 μV (rms) is applied across the same impedance.

To convert x dBμV to microvolts:

$$\text{Signal level in microvolts} = 10^{\left(\frac{x}{20}\right)}$$

To convert dBmV to dBμV, add 60 to the dBmV reading:

$$x \text{ dBmV} = (x+60) \text{ dB}\mu\text{V}$$

mW

To determine the power, in milliwatts, which is represented by a reading in dBmV, assuming an impedance of 75Ω:

To convert x dBmV to milliwatts:

$$\text{Signal power in milliwatts} = \frac{10^{\left(\frac{x}{10}\right)}}{75 * 1000}$$

dBm

A measurement of ‘x dBm’ indicates that a particular signal has a power of x dB greater than (or ‘above’) 1 milliwatt. A negative dBm value indicates that the signal is less than (‘below’) 1 milliwatt.

To convert x dBm to milliwatts:

$$\text{Signal power in milliwatts} = 10^{\left(\frac{x}{10}\right)}$$

Power expressed in dBmV can be converted to power expressed in dBm, as follows (the impedance is assumed to be 75Ω:

To convert x dBmV directly to dBm:

$$\text{Signal power in dBm} = 10 * \log\left[\frac{10^{\left(\frac{x}{10}\right)}}{75 * 1000}\right]$$

The inverse operation is also possible:

To convert x dBm directly to dBmV:

$$\text{Signal level in dBmV} = 10 * \log\left[75 * 1000 * 10^{\left(\frac{x}{10}\right)}\right]$$

Impedance Mismatch

It frequently happens that the input impedance of a measuring device (spectrum analyzer; field strength meter, etc.) does not match the impedance of the system under test. In such a case, a correction must be made to the reading displayed on the instrument.

$$\text{Correction (in dB)} = 10 * \log\left(\frac{Z_i}{Z_S}\right)$$

Where Z_i is the impedance of the instrument, and Z_S is the impedance of the system under test.

Table of Conversions

The following table lists the conversions between different units of measurement for the range of signal levels commonly encountered in Broadband networks. The equations described in the previous two pages were used in the compilation of this table.

dBmV	mV	dBμV	mW	dBm	dBmV	mV	dBμV	mW	dBm
0	1.0	60		-48.8					
1	1.1	61		-47.8	26	20.0	86	0.0053	-22.8
2	1.3	62		-46.8	27	22.4	87	0.0067	-21.8
3	1.4	63		-45.8	28	25.1	88	0.0084	-20.8
4	1.6	64		-44.8	29	28.2	89	0.0106	-19.8
5	1.8	65		-43.8	30	31.6	90	0.0133	-18.8
6	2.0	66		-42.8	31	35.5	91	0.0168	-17.8
7	2.2	67		-41.8	32	39.8	92	0.0211	-16.8
8	2.5	68	Less	-40.8	33	44.7	93	0.0266	-15.8
9	2.8	69	than	-39.8	34	50.1	94	0.0335	-14.8
10	3.2	70	0.0010	-38.8	35	56.2	95	0.0422	-13.8
11	3.5	71		-37.8	36	63.1	96	0.0531	-12.8
12	4.0	72		-36.8	37	70.8	97	0.0668	-11.8
13	4.5	73		-35.8	38	79.4	98	0.0841	-10.8
14	5.0	74		-34.8	39	89.1	99	0.1059	-9.8
15	5.6	75		-33.8	40	100.0	100	0.1333	-8.8
16	6.3	76		-32.8	41	112.2	101	0.1679	-7.8
17	7.1	77		-31.8	42	125.9	102	0.2113	-6.8
18	7.9	78		-30.8	43	141.3	103	0.2660	-5.8
19	8.9	79	0.0011	-29.8	44	158.5	104	0.3349	-4.8
20	10.0	80	0.0013	-28.8	45	177.8	105	0.4216	-3.8
21	11.2	81	0.0017	-27.8	46	199.5	106	0.5308	-2.8
22	12.6	82	0.0021	-26.8	47	223.9	107	0.6682	-1.8
23	14.1	83	0.0027	-25.8	48	251.2	108	0.8413	-0.8
24	15.8	84	0.0033	-24.8	49	281.8	109	1.0591	0.2
25	17.8	85	0.0042	-23.8	50	316.2	110	1.3333	1.2

Field Strength (leakage)

Leakage from a Broadband network is measured using a standard dipole antenna connected to a signal level measuring device such as a spectrum analyzer.

If the signal level of a particular video carrier measured in such a way is x dBmV, then the actual field strength is given by the following formula:

$$\text{Field strength in microvolts per meter } (\mu V/m) = 21 * F * 10^{\left(\frac{x}{20}\right)}$$

Where F is the frequency, in MHz, of the video carrier being measured.

Cable Loss Ratio

The ratio of the attenuation in coaxial cable, expressed in dB, at two frequencies is approximately equal to the square root of the ratio of the frequencies:

$$\text{Approximate cable loss ratio} = \sqrt{\left(\frac{F_H}{F_L}\right)}$$

Example: A 100 ft. length of 0.5 inch coaxial cable has a loss of 1.32 dB at 300 MHz. What is the loss at 600 MHz?

$$\text{Approximate cable loss ratio} = \sqrt{\left(\frac{600}{300}\right)} = \sqrt{2} = 1.414$$

Therefore the approximate loss at 600 MHz is 1.32 x 1.414 = 1.87 dB.

Exact Cable Loss Ratio

A more accurate determination of cable loss ratio can be obtained from the formula:

$$L_f = \frac{L_0}{1+\alpha}\left\{\sqrt{\frac{f}{f_0}} + \left(\frac{f}{f_0}\right)\right\}$$

Where L_f = loss, in dB, at the desired frequency;
L_0 = loss, in dB, at the reference frequency;
α = cable shape factor;
f_0 = reference frequency in MHz, and
f = desired frequency in MHz

Cable shape factor (α) is a parameter associated with a particular type and manufacturer of cable. In practice, the value of α is determined empirically.

BER (Bit Error Ratio)

In a digital communications link, Bit Error Ratio is defined as the ratio of the number of defective bits received to the total number of bits transmitted:

$$\text{Bit Error Ratio} = \frac{\text{Number of defective bits}}{\text{Number of bits transmitted}}$$

For example, if a BER test-set displays a reading of 2.3e-8, this means that the Bit Error Ratio is 0.000000023

The Bit Error <u>Rate</u> is calculated by taking the reciprocal of the Bit Error <u>Ratio</u>. In the above example, a Bit Error Ratio of 2.3e-8 means that errors are being received at the rate of one defective bit in every 4.35×10^7 bits received,

because $\left(\frac{1}{2.3 \times 10^{-8}} = 4.35 \times 10^7\right)$

When measuring BER, and particularly when testing for very low error rates, it is advisable to allow a sufficiently long measurement interval in order to obtain a statistically meaningful result. As a general guideline, the measurement interval should be one order of magnitude greater than the interval in which one error may be expected.

For example, if a Bit Error Rate of one defective bit in 10^8 bits is expected (BER = 1.0e-8), and the transmission rate is 1.544 Mbps, then one error may be expected every 64.8 seconds. (10^8 divided by 1.544 x 10^6). Therefore to obtain a statistically meaningful result an interval of 648 seconds (10.8 minutes) should be allowed. It is understood th
at, for very low error-rates, this procedure may not be practicable.

MER (Modulation Error Ratio)

The Signal-to-Noise Ratio (SNR) is often used as a measure of the potential impairment in a digital signal. However, SNR, as measured on a conventional spectrum analyzer, does not provide information about phase disturbances in the signal, which are critical in the case of phase/amplitude modulation schemes such as QAM.

A better parameter is Modulation Error Ratio. In the constellation diagram of a QAM signal, there is a ideal 'spot', defined by the I and Q co-ordinates, for each possible vector $\left(I_j, Q_j\right)$.
In a practical system, this ideal point is seldom hit exactly, due to several imperfections in the transmission link, such as quantizing error, rounding errors, noise, and phase jitter. This deviation of a real vector from the ideal spot in the signal constellation can be expressed as an error vector $\left(\delta I_j, \delta Q_j\right)$.

Mathematically, MER is equal to the root mean square magnitude of the ideal vector points divided by the root mean square magnitude of the error vectors.

Therefore,

$$\text{MER} = \frac{\sqrt{\frac{1}{N}.\sum_{j=1}^{N}\left(I_j^{\,2}+Q_j^{\,2}\right)}}{\sqrt{\frac{1}{N}.\sum_{1=j}^{N}\left(\delta I_j^{\,2}+\delta Q_j^{\,2}\right)}}$$

Expressed in decibel notation, this becomes:

$$\text{MER}(\text{dB}) = 10.\log\left\{\frac{\frac{1}{N}.\sum_{j=1}^{N}\left(I_j^{\,2}+Q_j^{\,2}\right)}{\frac{1}{N}.\sum_{j=1}^{N}\left(\delta I_j^{\,2}+\delta Q_j^{\,2}\right)}\right\}$$

The DVB project uses MER as the figure of merit test for modulation quality.

EVM (Error Vector Magnitude)

EVM is related to MER in that it is a measure of the deviation of the vectors of a phase/amplitude modulated signal from the ideal points in the constellation. It is defined as the root mean square magnitude of the error vectors divided by the maximum ideal vector magnitude, and is expressed as a percentage:

$$\text{EVM}(\%) = \frac{\sqrt{\frac{1}{N}.\sum_{j=1}^{N}\left(\delta I_j^{\,2}+\delta Q_j^{\,2}\right)}}{S_{max}} \text{ x } 100$$

SYSTEM PERFORMANCE CALCULATIONS

Types of Impairment

The performance of a Broadband network is usually defined in terms of the unwanted distortion and noise components produced in the network, and their effects on video signals. Even when the network is no longer a 'pure' CATV system and is, instead, carrying a mixture of services, it is still common practice to define network quality by reference to the relationship between distortion, noise, and a reference video signal level.

Broadband engineers recognize five primary imperfections in network performance, all measured relative to the video carrier level: total random noise, composite triple-beat, composite second-order beat, cross-modulation, and hum modulation. In the following section, these parameters are defined, and the rules for calculating total network performance are given.

Noise

All amplifiers generate noise, and a broadband network is also susceptible to noise from external sources. The combined noise level is measured relative to video carrier level:

> Carrier-to-Noise Ratio (CNR) is defined as the ratio (in decibels) of the peak video carrier power to the average noise power, normalized to a specified bandwidth.

The noise performance of a single amplifier is most commonly specified as the noise figure:

To convert Noise Figure (NF) to CNR:

$$CNR = 65.2 - 10.\log(\Delta f) + L_i - NF$$

Where Δf = measurement bandwidth in MHz

L_i = amplifier input level (dBmV)

and the temperature is assumed to be 68°F (20°C)

Values of Δf for a number of different television systems are as follows:

System	I	B, G	K1, L	M, N
Video bandwidth*	6.75	5.75	7.25	4.95
Noise measurement bandwidth	5.08	4.75	5.58	4.00

* Includes lower sideband

Example: for an amplifier with a Noise Figure of 9 dB and an NTSC input signal at a level of +20 dBmV, the resultant CNR at 68°F is
65.2 - 6 + 20 – 9 = 70.2 dB (always expressed as a positive quantity, in dB).

Composite Triple-Beat (CTB)

The output of an ideal amplifier would be an exact replica of the input signal: such an amplifier would be referred to as 'perfectly linear'. In practice, of course, amplifiers deviate from perfect linearity, and the result, in the case of a broadband, multi-channel signal, is an output containing a large number of low-level unwanted components. These components are an aggregate of input signal harmonics, and interactions between input signals.

One category of such signals comprises the so-called 'triple beat' components, which result from harmonics and interactions of the form:

$$3f_1$$
$$f_1 \pm f_2 \pm f_3$$
$$2f_1 + f_2$$
$$2f_1 - f_2$$

where f_1, f_2 and f_3 are the frequencies of any three input signals. It will be seen that, in a large-capacity network, the number of such combinations which fall inside the network pass-band is very large. The totality of all the spurious signals that result from these combinations is referred to as the Composite Triple-Beat, and triple-beat groupings generally lie at, or close to, the video carriers.
Therefore:

> Composite Triple-Beat (CTB) is defined as the ratio (in decibels) of the peak video carrier power to the peak of the aggregate distortion signal lying at the video carrier frequency.

This parameter is measured with unmodulated video carriers, and with the carrier in the channel of interest turned off.

Broadband equipment manufacturers specify the CTB performance of their amplifiers at a specific output level (for example, +46 dBmV). This is because CTB varies as the input level to the internal amplifier module (usually a hybrid gain block) is raised or lowered. This effect will be discussed in detail later in this section.

Composite Second Order (CSO)

Another category of unwanted signal components produced by an amplifier consists of the 'second order' beat components, which result from harmonics and interactions of the form:

$2f_1$
$f_1 + f_2$
$f_1 - f_2$

where f_1 and f_2 are the frequencies of any two input signals. The number of such combinations in a large-capacity network is less than that produced by third-order distortions, but is nevertheless significant. The totality of all the spurious signals that result from these combinations is referred to as the Composite Second Order beat, and CSO groupings generally lie at either 0.75 or 1.25 MHz above and below the video carriers. Therefore:

> Composite Second Order (CSO) is defined as the ratio (in decibels) of the peak video carrier power to the peak of the aggregate distortion signal lying at ±0.75 MHz or ±1.25 MHz relative to the video carrier frequency.

This parameter is measured with unmodulated video carriers.

As in the case of Composite Triple Beat, Broadband equipment manufacturers specify the CSO performance of their amplifiers at a specific output level (for example, +46 dBmV). This is because CSO varies as the input level to the internal amplifier module (usually a hybrid gain block) is raised or lowered. This effect will be discussed in detail later in this section.

Cross Modulation (XMOD)

Non-linearities in amplifier also give rise to Cross-Modulation, which is the unwanted modulation of any particular video carrier by the signals being carried in other channels in the system. Because each video channel contains a constant, high-level signal component at the horizontal line frequency (15.734 kHz in the NTSC system), this is the most noticeable component of Cross-Modulation. Therefore:

> Cross Modulation (XMOD) is defined as the ratio of the peak-to-peak amplitude of the modulation, on the test carrier (caused by the signals on other carriers), to the peak level of the carrier.

Cross modulation (cont'd)

It is usually measured on an unmodulated carrier, with all other carriers in the system being synchronously modulated to a depth of 100% by a square-wave at the horizontal line-rate.

The Cross Modulation performance of a single amplifier is specified at a given output level, and changes as that level is raised or lowered.

Hum Modulation

This form of distortion is a result of the unwanted modulation of a particular video carrier by components of the system power supply. Therefore:

> Hum Modulation is defined as the ratio (in decibels) of the peak video carrier power to the peak of the unwanted modulation sidebands at 50 or 60 Hz and harmonics (depending on power-line frequency), relative to the video carrier frequency.

It practice, Hum Modulation is measured as the percentage depth of modulation of a video carrier, using an oscilloscope, then converted to decibels.

To convert percentage modulation to decibels:

$$\text{Hum modulation in dB} = 20 * \log\left(\frac{M}{100}\right)$$

Where M = modulation depth expressed as a percentage.

Single Amplifier Performance

As mentioned above, the noise and distortion performance of a particular amplifier are always stated at a specific output signal level and tilt. If an amplifier is operated with different output characteristics, the noise and distortion performance figures will change. These relationships are described below:

Effect of Changing Output Level

If amplifier output level is changed, but tilt remains as specified in the manufacturer's recommendations, then the following modifications to amplifier performance must be made:

$$CNR_{new} = CNR_{ref} + (L_{new} - L_{ref})$$ *(CNR given as a positive number)*

Where CNR_{new} = new Carrier-to-Noise ratio;
CNR_{ref} = reference (old) Carrier-to-Noise ratio;
L_{new} = new amplifier output level, and
L_{ref} = reference (old) amplifier output level

$$CTB_{new} = CTB_{ref} - 2*(L_{new} - L_{ref})$$ *(CTB given as a positive number)*

Where CTB_{new} = new Composite Triple-Beat, and
CTB_{ref} = reference (old) Composite Triple-Beat

$$CSO_{new} = CSO_{ref} - (L_{new} - L_{ref})$$ *(CSO given as a positive number)*

Where CSO_{new} = new Composite Second Order, and
CSO_{ref} = reference (old) Composite Second Order

$$XMOD_{new} = XMOD_{ref} - 2*(L_{new} - L_{ref})$$ *(XMOD given as a positive number)*

Where $XMOD_{new}$ = new Cross Modulation, and
$XMOD_{ref}$ = reference (old) Cross Modulation

Thus it can be seen that Carrier-to-Noise ratio is improved when amplifier output level is raised, whereas all distortions are worsened.

Effect of Changing Tilt

If amplifier tilt is changed, but output level at the high-frequency end of the spectrum remains as specified in the manufacturer's recommendations, then modifications to amplifier performance must be made. *The following formulas are based on empirical data.* In all cases, 'tilt' is assumed to be positive; that is, the signal level at the high-frequency end of the spectrum is greater than that at the low-frequency end. An increase in tilt is therefore equivalent to a decrease in the signal level at the low-frequency end.

Carrier-to-Noise ratio at the high frequency end of the spectrum remains unchanged. At the low-frequency limit,

$$CNR_{new} = CNR_{ref} - (T_{new} - T_{ref})$$ *(CNR given as a positive number)*

	CNR_{new}	= new Carrier-to-Noise ratio;
	CNR_{ref}	= reference (old) Carrier-to-Noise ratio;
	T_{new}	= new amplifier output tilt, and
	T_{ref}	= reference (old) amplifier output tilt.

$$CTB_{new} = CTB_{ref} + 0.8*(T_{new} - T_{ref})$$ *(CTB given as a positive number)*

Where	CTB_{new}	= new Composite Triple-Beat, and
	CTB_{ref}	= reference (old) Composite Triple-Beat

$$CSO_{new} = CSO_{ref} + 0.33*(T_{new} - T_{ref})$$ *(CSO given as a positive number)*

Where	CSO_{new}	= new Composite Second Order, and
	CSO_{ref}	= reference (old) Composite Second Order

$$XMOD_{new} = XMOD_{ref} + 0.5*(T_{new} - T_{ref})$$ *(XMOD given as a positive number)*

Where	$XMOD_{new}$	= new Cross Modulation, and
	$XMOD_{ref}$	= reference (old) Cross Modulation

In summary, Carrier-to-Noise ratio at low frequencies is worsened when amplifier output tilt is increased, whereas all distortions are improved.

Cascade Performance

Identical Amplifiers and Operating Levels

For a cascade of identical amplifiers, all operating with the same output level and tilt, end-of-line (EOL) performance can be easily calculated as follows:

For Carrier-to-Noise ratio and Composite Second Order,

$$CNR_{EOL} = CNR_{AMP} - 10*\log(N)$$
$$CSO_{EOL} = CSO_{AMP} - 10*\log(N)$$

(CNR and CSO given as a positive numbers)

Where N = number of amplifiers in cascade

For Composite Triple-Beat, Cross Modulation and Hum Modulation,

$$CTB_{EOL} = CTB_{AMP} - 20*\log(N)$$
$$XMOD_{EOL} = XMOD_{AMP} - 20*\log(N)$$
$$HMOD_{EOL} = HMOD_{AMP} - 20*\log(N)$$

(CTB, XMOD and HMOD given as positive numbers)

Dissimilar Amplifiers and/or Operating Levels

When calculating the end-of-line performance for a cascade of different amplifier types, or identical amplifiers which operate with different output levels and tilts, a more complex calculation is required.

For Carrier-to-Noise ratio and Composite Second Order,

$$CNR_{EOL} = -10*\log\left[10^{\left(\frac{-CNR_1}{10}\right)} + 10^{\left(\frac{-CNR_2}{10}\right)} + 10^{\left(\frac{-CNR_3}{10}\right)} + \bullet\bullet\right]$$

Where CNR_1, CNR_2, CNR_3 etc. are the Carrier-to-Noise performance figures for the separate amplifiers in the cascade.

Dissimilar Amplifiers and/or Operating Levels (cont'd)

And,

$$CSO_{EOL} = -10 * \log\left[10^{\left(\frac{-CSO_1}{10}\right)} + 10^{\left(\frac{-CSO_2}{10}\right)} + 10^{\left(\frac{-CSO_3}{10}\right)} + \bullet\bullet\right]$$

Where CSO_1, CSO_2, CSO_3 etc. are the Composite Second Order performance figures for the separate amplifiers in the cascade.

NOTE: It is assumed that both CNR and CSO are expressed as positive numbers.

For Composite Triple-Beat, Cross Modulation and Hum Modulation,

$$CTB_{EOL} = -20 * \log\left[10^{\left(\frac{-CTB_1}{20}\right)} + 10^{\left(\frac{-CTB_2}{20}\right)} + 10^{\left(\frac{-CTB_3}{20}\right)} + \bullet\bullet\right]$$

$$XMOD_{EOL} = -20 * \log\left[10^{\left(\frac{-XMOD_1}{20}\right)} + 10^{\left(\frac{-XMOD_2}{20}\right)} + 10^{\left(\frac{-XMOD_3}{20}\right)} + \bullet\bullet\right]$$

$$HMOD_{EOL} = -20 * \log\left[10^{\left(\frac{-HMOD_1}{20}\right)} + 10^{\left(\frac{-HMOD_2}{20}\right)} + 10^{\left(\frac{-HMOD_3}{20}\right)} + \bullet\bullet\right]$$

Where $\left\{\begin{matrix} CTB_1, CTB_2, CTB_3, etc. \\ XMOD_1, XMOD_2, XMOD_3, etc. \\ HMOD_1, HMOD_2, HMOD_3, etc. \end{matrix}\right\}$ are the CTB, XMOD and HMOD performance figures for the separate amplifiers in the cascade.

NOTE: It is assumed that CTB, XMOD and HMOD are expressed as positive numbers.

WEIGHTS and MEASURES

The following tables provide conversions between U.S. units and their metric equivalents. Metric units are defined by the SI (Système International), which came into effect in October 1960.

The tables are by no means exhaustive: they include only those weights and measures which are related, directly and indirectly, to the broadband industry.

Length (general)

metric to U.S.		
1 millimeter (mm)		= 0.0394 inch
1 centimeter (cm)	= 10 mm	= 0.3937 inch
1 meter (m)	= 100 cm	= 1.0936 yard
1 kilometer (km)	= 1000 m	= 0.6214 mile

U.S. to metric		
1 inch (in)		= 25.400 mm
1 foot (ft)	= 12 in	= 30.48 cm
1 yard (yd)	= 3 ft	= 0.9144 m
1 mile (mi)	= 1760 yd	= 1.6093 km

(The SI standard unit of length is the meter)

Length (optics)

1 angstrom (Å)	= 10^{-10} m	
1 nanometer (nm)	= 10^{-9} m	= 10 Å
1 micrometer (μm)	= 10^{-6} m	= 1000 nm

(The micrometer is frequently referred to as the ‘micron’)

Area

metric to U.S.		
1 square centimeter (cm^2)		= 0.1550 sq inch
1 square meter (m^2)	= 10^4 cm^2	= 10.7639 sq foot
		= 1.1960 sq yard
1 square kilometer (km^2)	= 10^6 m^2	= 247.105 acre
	= 100 hectare	= 0.3861 sq mile

U.S. to metric		
1 square inch (in^2)		= 6.4516 cm^2
1 square foot (ft^2)	= 144 in^2	= 0.0929 m^2
1 square yard (yd^2)	= 9 ft^2	= 0.8361 m^2
1 acre (ac)	= 4840 yd^2	= 4046.86 m^2
		= 0.4047 hectare
1 square mile (mi^2)	= 640 ac	= 259 hectare

(The SI standard unit of area is the square meter)

Mass

metric to U.S.		
1 gram (g)		= 0.0353 ounce
1 kilogram (kg)	= 1000 g	= 2.2046 pound
1 tonne (t)	= 1000 kg	= 2204.6 pound
		= 0.9842 ton

(The ‘tonne’ is sometimes referred to as the ‘metric ton’)

U.S. to metric		
1 ounce (oz)		= 28.35 g
1 pound (lb)	= 16 oz	= 0.4536 kg
1 ton	= 2240 lb	= 1016.05 kg
		= 1.0161 tonne

(The SI standard unit of mass is the kilogram)

Volume

metric to U.S.

1 cubic centimeter (cm^3)		= 0.0610 cu. inch
		= 0.0338 fl. ounce
1 deciliter (dl)	= 100 cm^3	= 3.3814 fl. ounce
1 liter (l)	= 1000 cm^3	= 2.1134 pints
		= 0.2642 gallon
		= 0.0353 cu. foot
1 cubic meter (m^3)	= 1000 l	= 35.3147cu. foot
		= 1.3079 cu. yard

U.S. to metric

1 cubic inch (in^3)		= 16.3871 cm^3
1 fluid ounce	= 1.8047 in^3	= 29.5735 cm^3
1 pint (pt)	= 16 fl. ounce	= 4.7318 dl
		= 0.4732 l
1 gallon (gal)	= 8 pint	= 3.7854 l
1 cubic foot (ft^3)	= 7.4844 gallon	= 28.3168 l
1 cubic yard (yd^3)	= 27 cu. foot	= 0.7646 m^3

(The SI standard unit of volume is the cubic meter, although the liter is more popular)

Moment of force (torque)

metric to U.S.

1 Newton meter (N.m)	= 7.2307 ft - lb

U.S. to metric

1 foot - pound (ft - lb)	= 0.1383 N.m

(One foot-pound is the torque produced by a one-pound force acting at the end of a one-foot crank)

Metric multipliers

The following table presents the SI prefixes as defined in ISO standard 1000:1992

Factor	Prefix	
	Name	*Symbol*
10^{24}	yotta	Y
10^{21}	zetta	Z
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10	deca	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	µ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a
10^{-21}	zepto	z
10^{-24}	yocto	y

Care should be taken to ensure that the correct case (upper or lower) is used, to avoid confusion.
(e.g. M = mega; m = milli)

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