TTC DSL 専門委員会スペクトル管理サブワーキンググループ

日付：2003 年 7 月 3 日

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題名：クワッドスペクトルサービスのスペクトル適合性検討

弊社では、クワッドスペクトルを利用したサービスを検討しているが、本寄書においては、現在、ITU-T で提案されている仮称 G.992.1 AnnexQ のスペクトル適合性を示す。

G.992.1 AnnexQ のスペクトルは、既に JJ100.01 で規定がされている 0-1.104MHz の帯域においては、FDM-ADSL（G.992.1）と同一の PSD ないしは電力値が下回る PSD を持っているため、スペクトル適合性の計算は、表 1～表 3 及び図 1～図 8 の通りとなる

（※）ただし、このスペクトル適合性の計算の前提は、“ DSL スペクトル管理の基本的要件 ”に記載された線路条件・収容条件に基づいている。
また、この寄書では、干渉側の送信 PSD は、従来使用していた G.996.1 を参照している。

なお、全ての新伝送方式のクラスの分類をおこなうにあたっては、現在未確認方式のステータスのままサービス提供されている伝送方式のクラス整理を行ったうえで、検討がなされるべきである。

G.992.1 Annex.A/Cに対する干渉

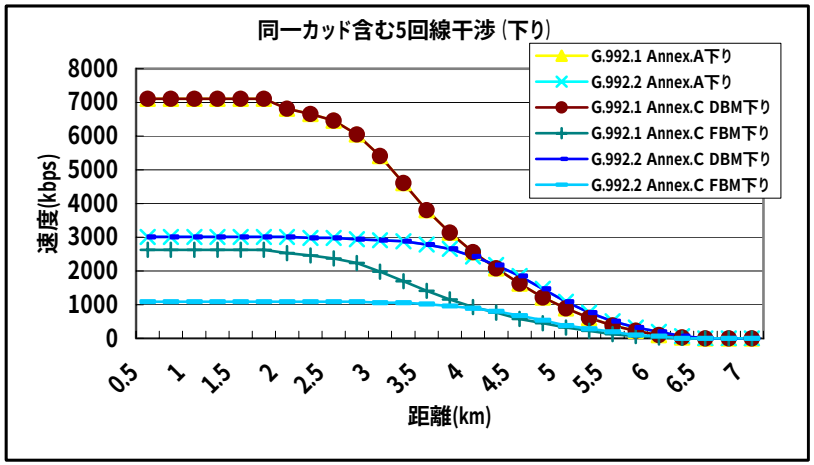


図1　同一カッドを含む5回線による下り信号の干渉

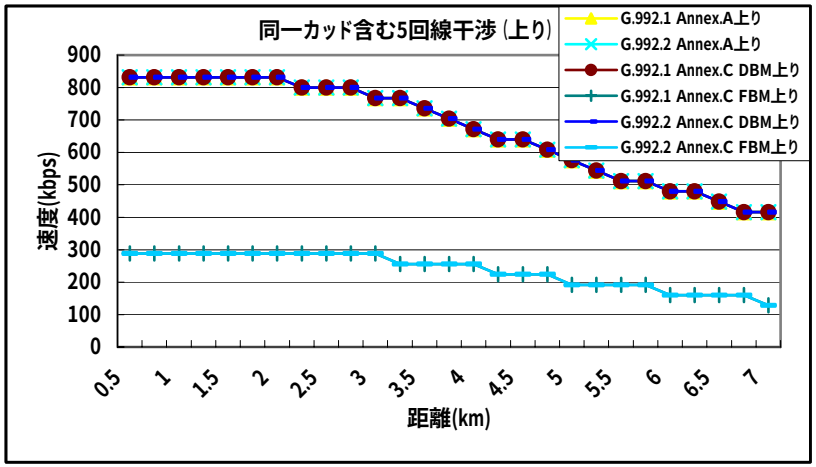


図2　同一カッドを含む5回線による上り信号の干渉

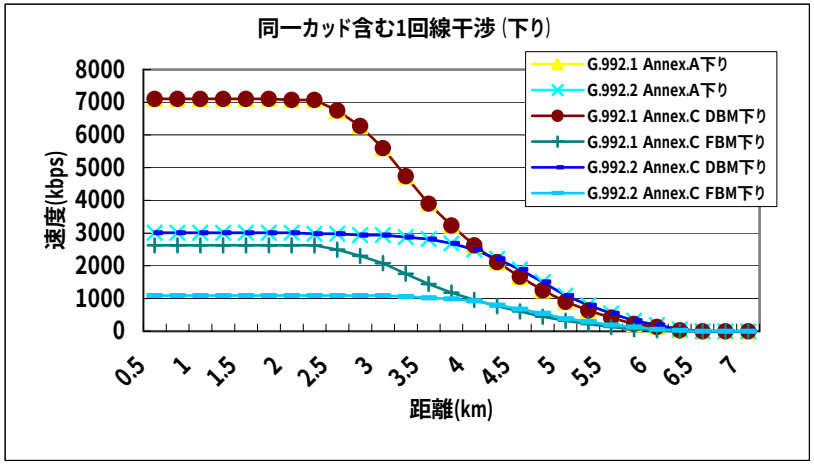


図3　同一カッドを含む1回線による下り信号の干渉

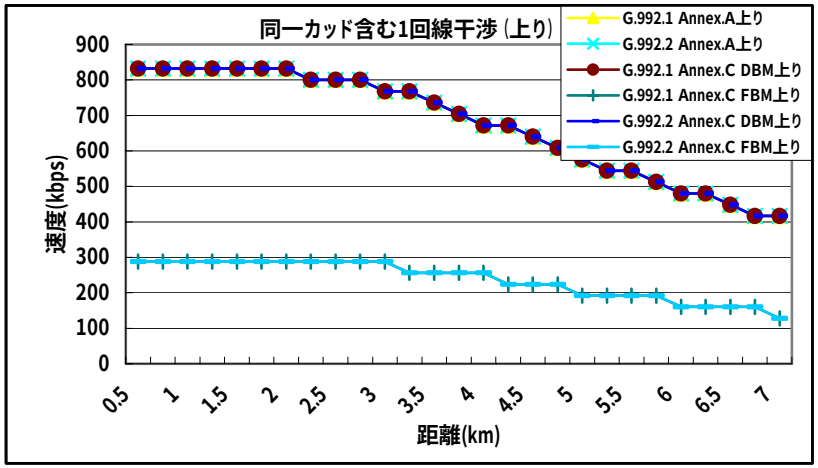
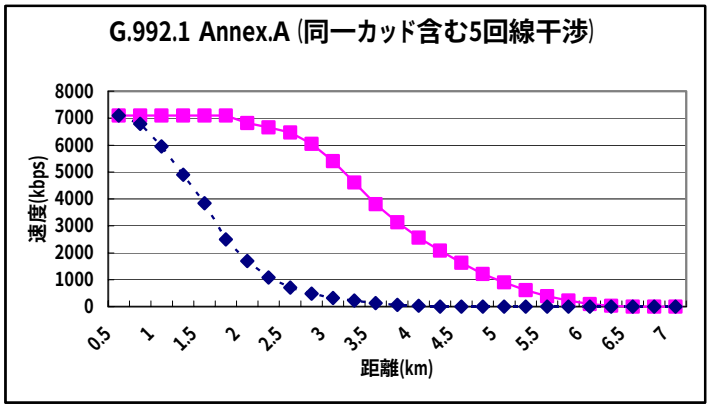
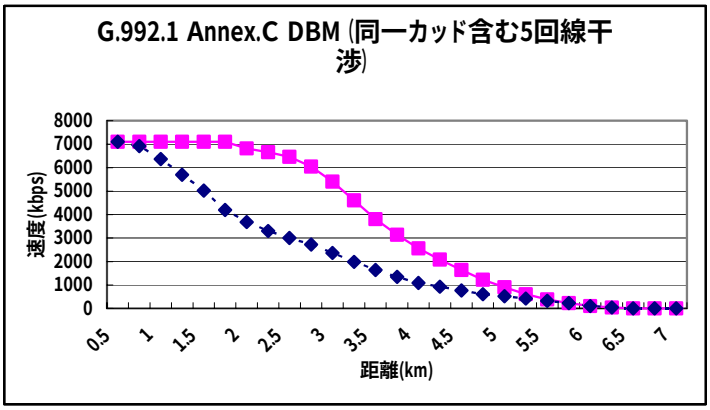
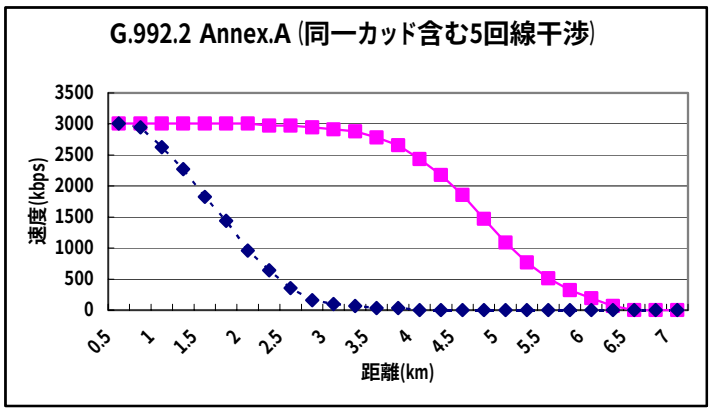


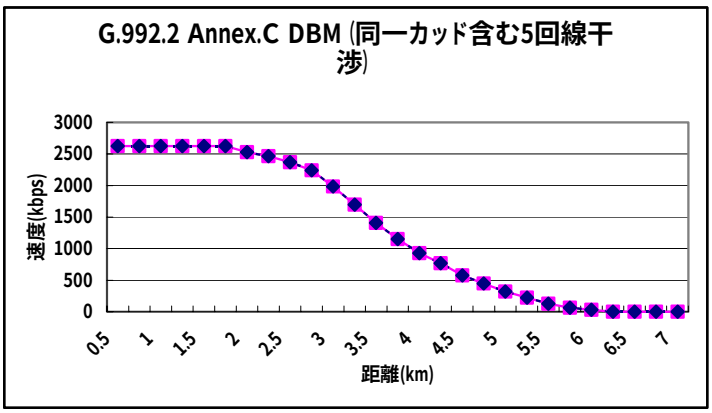
図4　同一カッドを含む1回線による上り信号の干渉

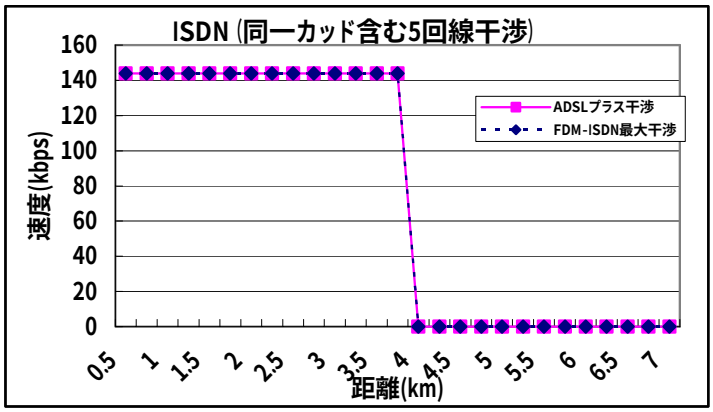
図5　同一カッド含む5回線干渉（下り）

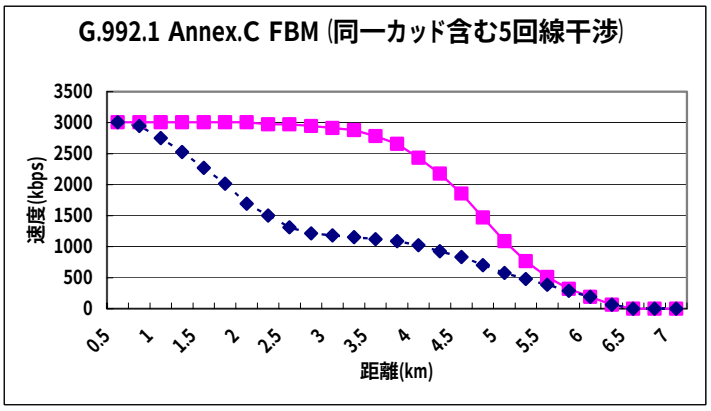












注：凡例は全て同じ

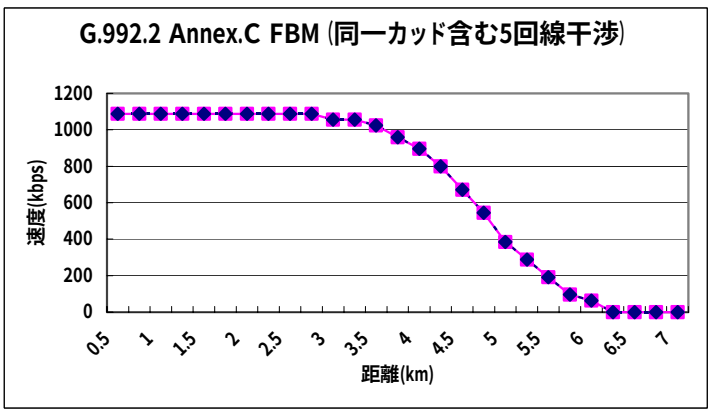
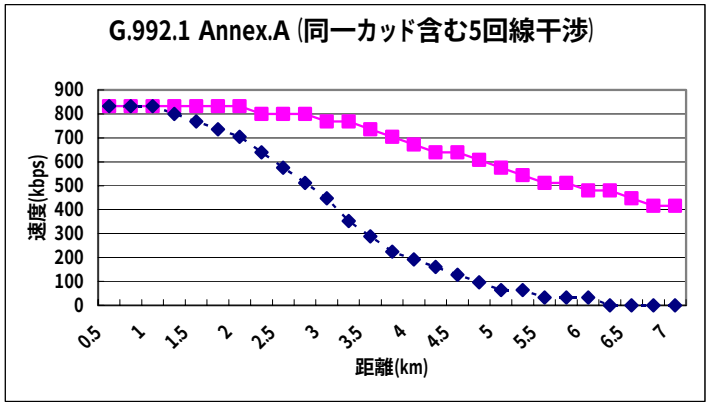
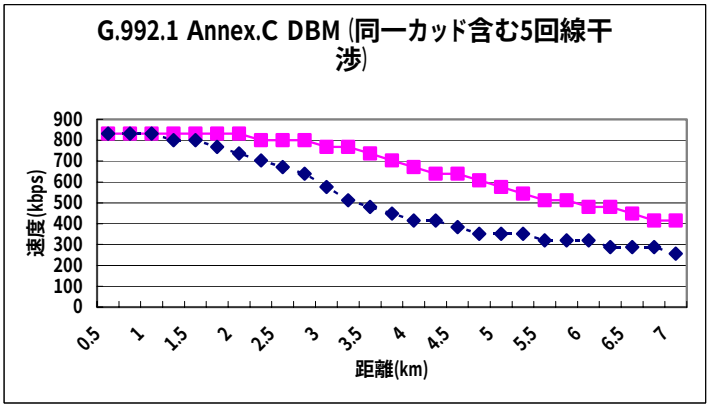
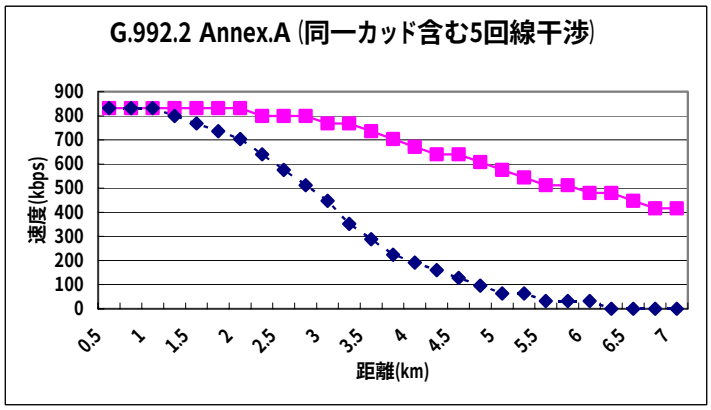
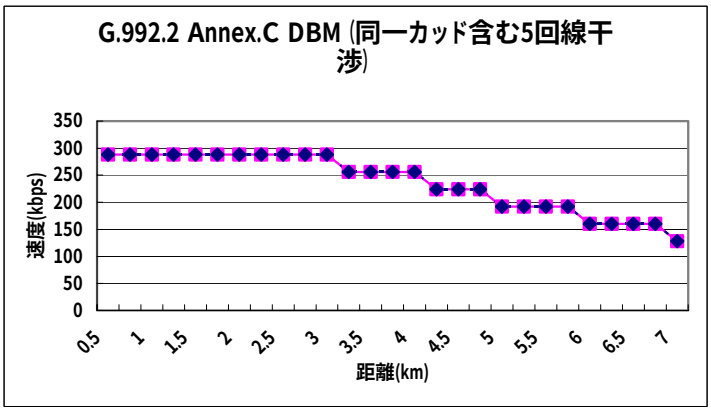


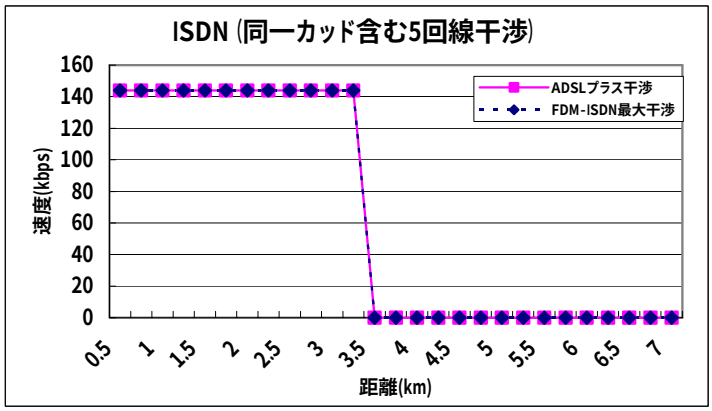
図6　同一カッド含む5回線干渉（上り）

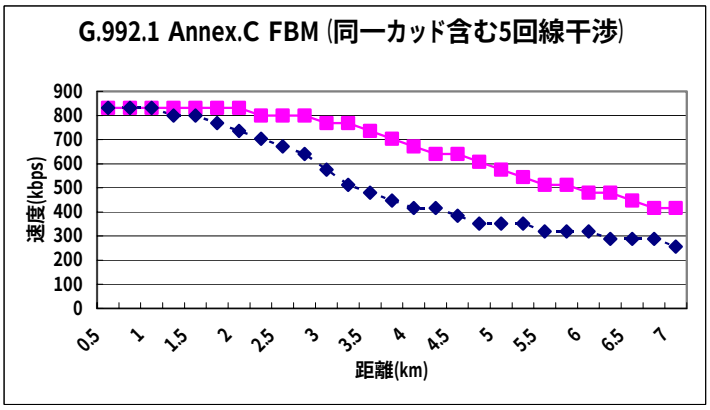












注：凡例は全て同じ

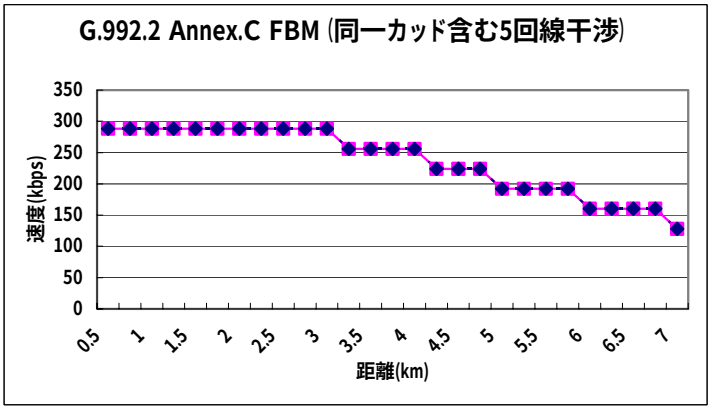
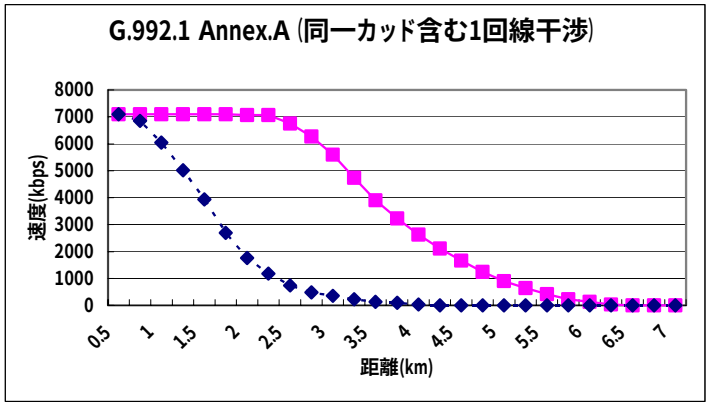
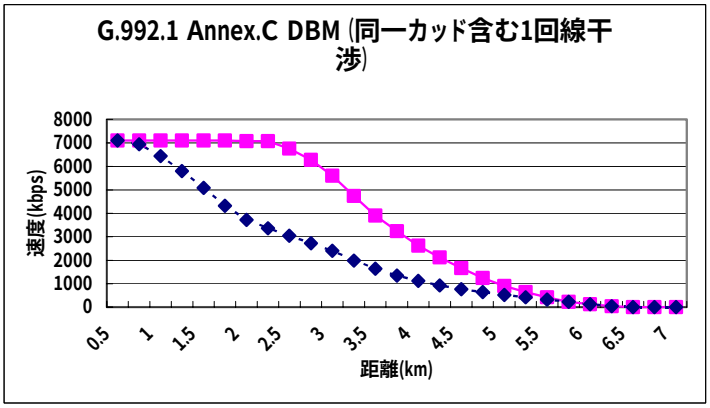
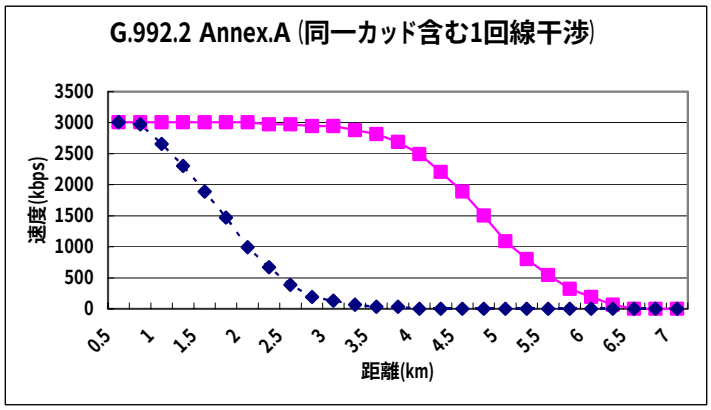
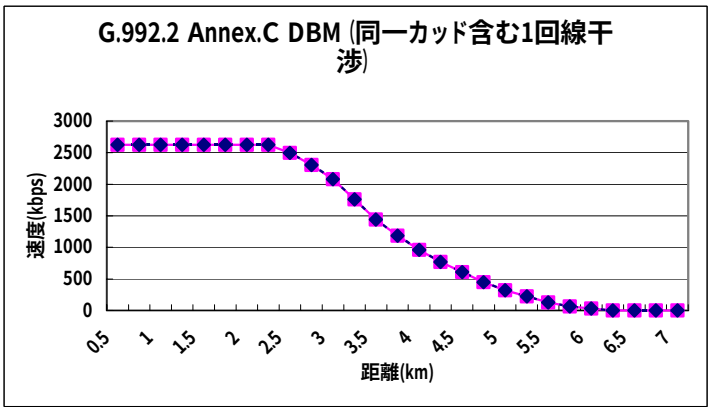


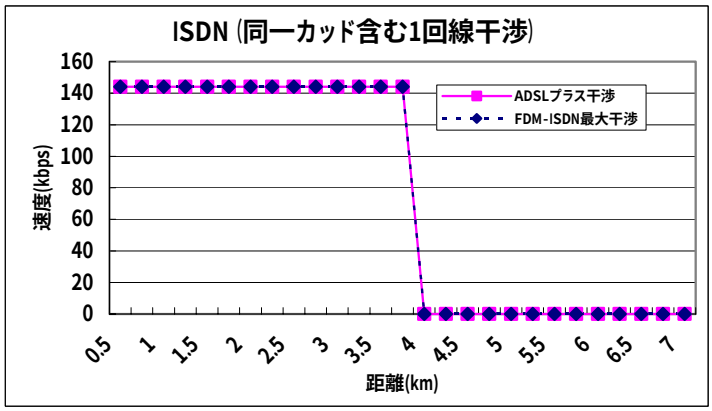
図7　同一カッド含む1回線干渉（下り）

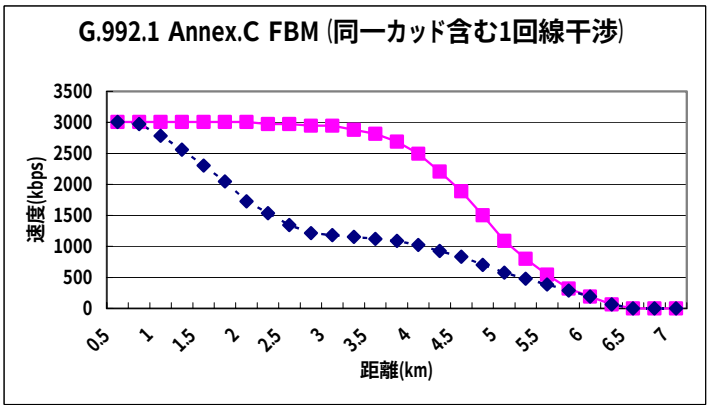












注：凡例は全て同じ

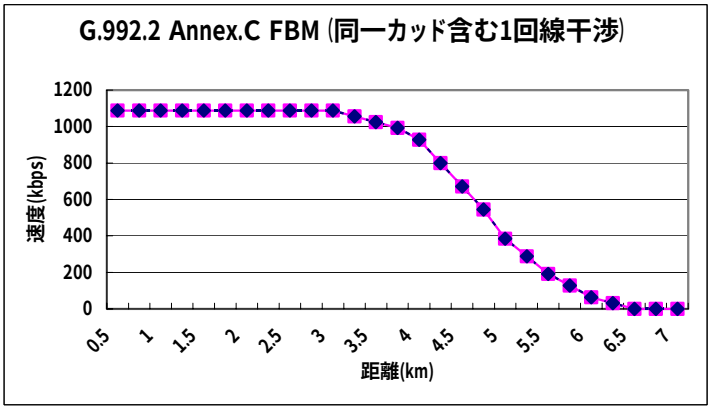
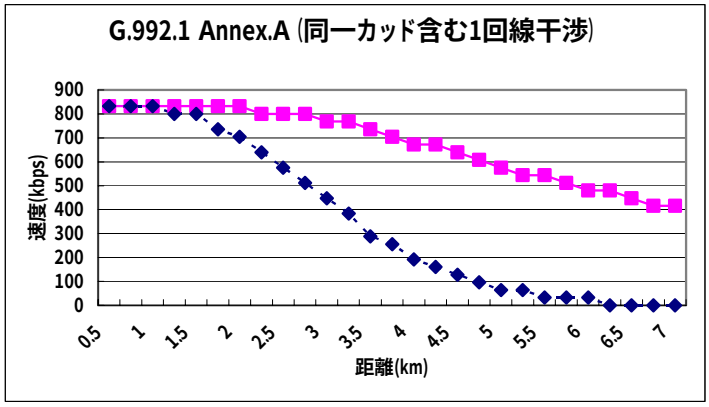
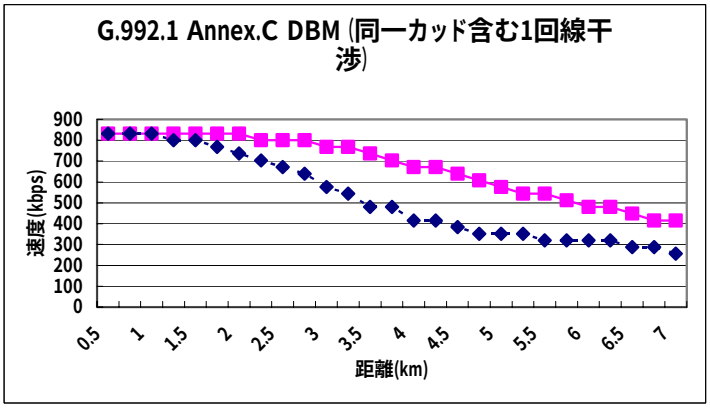
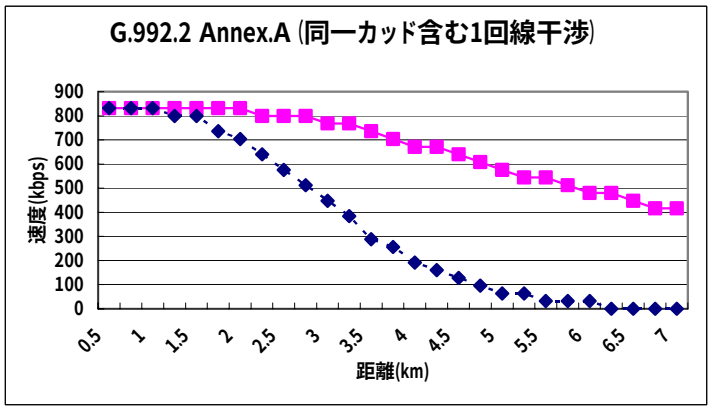
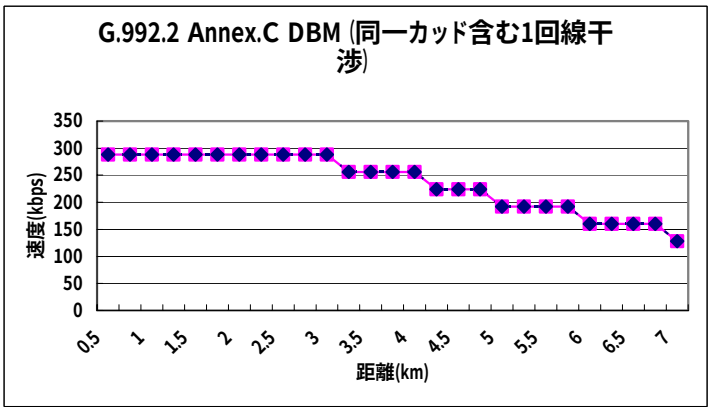


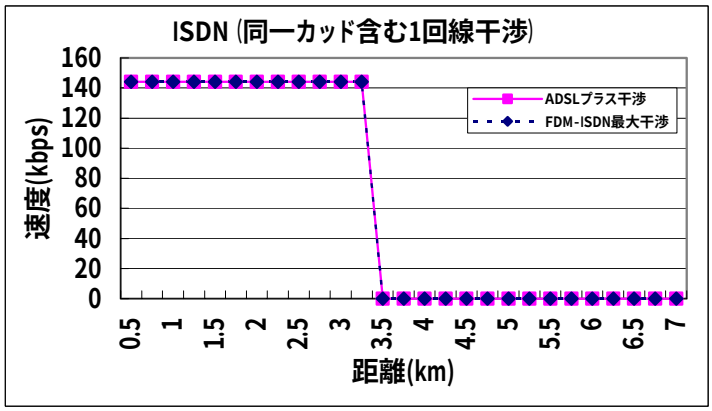
図8 同一カッド含む1回線干渉（上り）

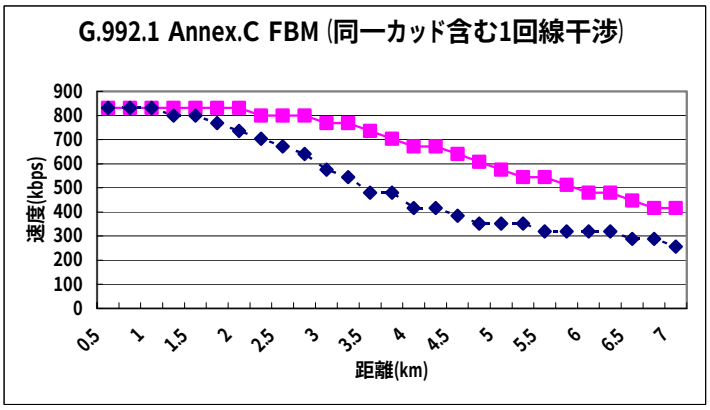












注：凡例は全て同じ

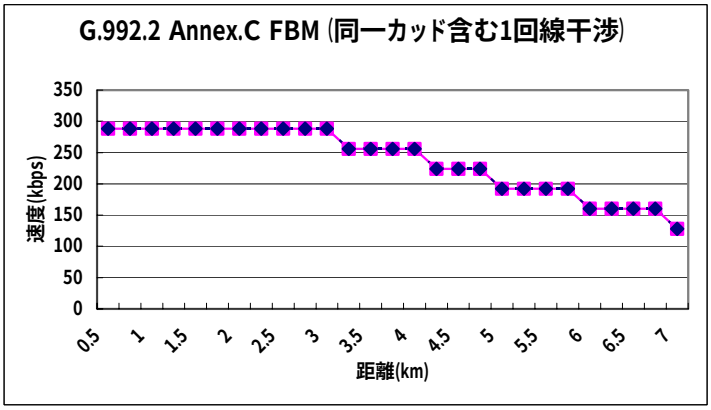


表1 ISDN, G.992.1 Annex.A/Cに対する干渉（同一カッド含む5回線）

距離	ISDN				G.992.1 AnnexA (FDM)				G.992.2 AnnexA				G.992.1 AnnexC								G.992.2 AnnexC							
													DBM				FBM				DBM				FBM			
	DS		US		DS		US		DS		US		DS		US		DS		US		DS		US		DS		US	
0.5	144	0	144	0	7104	0	832	0	3008	0	832	0	7104	0	832	0	2624	0	288	0	3008	0	832	0	1088	0	288	0
0.75	144	0	144	0	7104	320	832	0	3008	64	832	0	7104	192	832	0	2624	0	288	0	3008	64	832	0	1088	0	288	0
1	144	0	144	0	7104	1152	832	0	3008	384	832	0	7104	736	832	0	2624	0	288	0	3008	256	832	0	1088	0	288	0
1.25	144	0	144	0	7104	2208	832	32	3008	736	832	32	7104	1408	832	32	2624	0	288	0	3008	480	832	32	1088	0	288	0
1.5	144	0	144	0	7104	3264	832	64	3008	1184	832	64	7104	2080	832	32	2624	0	288	0	3008	736	832	32	1088	0	288	0
1.75	144	0	144	0	7104	4608	832	96	3008	1568	832	96	7104	2912	832	64	2624	0	288	0	3008	992	832	64	1088	0	288	0
2	144	0	144	0	6816	5120	832	128	3008	2048	832	128	6816	3136	832	96	2528	0	288	0	3008	1312	832	96	1088	0	288	0
2.25	144	0	144	0	6656	5568	800	160	2976	2336	800	160	6656	3360	800	96	2464	0	288	0	2976	1472	800	96	1088	0	288	0
2.5	144	0	144	0	6464	5760	800	224	2976	2624	800	224	6464	3456	800	128	2368	0	288	0	2976	1664	800	128	1088	0	288	0
2.75	144	0	144	0	6048	5568	800	288	2944	2784	800	288	6048	3328	800	160	2240	0	288	0	2944	1728	800	160	1088	0	288	0
3	144	0	144	0	5408	5088	768	320	2912	2816	768	320	5408	3040	768	192	1984	0	288	0	2912	1728	768	192	1056	0	288	0
3.25	144	0	144	0	4608	4384	768	416	2880	2816	768	416	4608	2624	768	256	1696	0	256	0	2880	1728	768	256	1056	0	256	0
3.5	144	0	0	0	3808	3680	736	448	2784	2752	736	448	3808	2176	736	256	1408	0	256	0	2784	1664	736	256	1024	0	256	0
3.75	144	0	0	0	3136	3072	704	480	2656	2624	704	480	3136	1792	704	256	1152	0	256	0	2656	1568	704	256	960	0	256	0
4	0	0	0	0	2560	2528	672	480	2432	2432	672	480	2560	1472	672	256	928	0	256	0	2432	1408	672	256	896	0	256	0
4.25	0	0	0	0	2080	2080	640	480	2176	2176	640	480	2080	1152	640	224	768	0	224	0	2176	1248	640	224	800	0	224	0
4.5	0	0	0	0	1632	1632	640	512	1856	1856	640	512	1632	864	640	256	576	0	224	0	1856	1024	640	256	672	0	224	0
4.75	0	0	0	0	1216	1216	608	512	1472	1472	608	512	1216	608	608	256	448	0	224	0	1472	768	608	256	544	0	224	0
5	0	0	0	0	896	896	576	512	1088	1088	576	512	896	384	576	224	320	0	192	0	1088	512	576	224	384	0	192	0
5.25	0	0	0	0	608	608	544	480	768	768	544	480	608	192	544	192	224	0	192	0	768	288	544	192	288	0	192	0
5.5	0	0	0	0	384	384	512	480	512	512	512	480	384	64	512	192	128	0	192	0	512	128	512	192	192	0	192	0
5.75	0	0	0	0	224	224	512	480	320	320	512	480	224	0	512	192	64	0	192	0	320	32	512	192	96	0	192	0
6	0	0	0	0	96	96	480	448	192	192	480	448	96	0	480	160	32	0	160	0	192	0	480	160	64	0	160	0
6.25	0	0	0	0	32	32	480	480	64	64	480	480	32	0	480	192	0	0	160	0	64	0	480	192	0	0	160	0
6.5	0	0	0	0	0	0	448	448	0	0	448	448	0	0	448	160	0	0	160	0	0	0	448	160	0	0	160	0
6.75	0	0	0	0	0	0	416	416	0	0	416	416	0	0	416	128	0	0	160	0	0	0	416	128	0	0	160	0
7	0	0	0	0	0	0	416	416	0	0	416	416	0	0	416	160	0	0	128	0	0	0	416	160	0	0	128	0

表2 ISDN, G.992.1 Annex.A/Cに対する干渉（同一カッド含む1回線）

距離	ISDN				G.992.1 AnnexA (FDM)				G.992.2 AnnexA				G.992.1 AnnexC								G.992.2 AnnexC							
													DBM				FBM				DBM				FBM			
	DS		US		DS		US		DS		US		DS		US		DS		US		DS		US		DS		US	
0.5	144	0	144	0	7104	0	832	0	3008	0	832	0	7104	0	832	0	2624	0	288	0	3008	0	832	0	1088	0	288	0
0.75	144	0	144	0	7104	256	832	0	3008	32	832	0	7104	160	832	0	2624	0	288	0	3008	32	832	0	1088	0	288	0
1	144	0	144	0	7104	1056	832	0	3008	352	832	0	7104	672	832	0	2624	0	288	0	3008	224	832	0	1088	0	288	0
1.25	144	0	144	0	7104	2080	832	32	3008	704	832	32	7104	1312	832	32	2624	0	288	0	3008	448	832	32	1088	0	288	0
1.5	144	0	144	0	7104	3168	832	32	3008	1120	832	32	7104	2016	832	32	2624	0	288	0	3008	704	832	32	1088	0	288	0
1.75	144	0	144	0	7104	4416	832	96	3008	1536	832	96	7104	2784	832	64	2624	0	288	0	3008	960	832	64	1088	0	288	0
2	144	0	144	0	7072	5312	832	128	3008	2016	832	128	7072	3360	832	96	2624	0	288	0	3008	1280	832	96	1088	0	288	0
2.25	144	0	144	0	7072	5888	800	160	2976	2304	800	160	7072	3712	800	96	2624	0	288	0	2976	1440	800	96	1088	0	288	0
2.5	144	0	144	0	6752	6016	800	224	2976	2592	800	224	6752	3712	800	128	2496	0	288	0	2976	1632	800	128	1088	0	288	0
2.75	144	0	144	0	6272	5792	800	288	2944	2752	800	288	6272	3552	800	160	2304	0	288	0	2944	1728	800	160	1088	0	288	0
3	144	0	144	0	5600	5248	768	320	2944	2816	768	320	5600	3200	768	192	2080	0	288	0	2944	1760	768	192	1088	0	288	0
3.25	144	0	144	0	4736	4512	768	384	2880	2816	768	384	4736	2752	768	224	1760	0	256	0	2880	1728	768	224	1056	0	256	0
3.5	144	0	0	0	3904	3776	736	448	2816	2784	736	448	3904	2272	736	256	1440	0	256	0	2816	1696	736	256	1024	0	256	0
3.75	144	0	0	0	3232	3136	704	448	2688	2656	704	448	3232	1888	704	224	1184	0	256	0	2688	1600	704	224	992	0	256	0
4	0	0	0	0	2624	2592	672	480	2496	2496	672	480	2624	1504	672	256	960	0	256	0	2496	1472	672	256	928	0	256	0
4.25	0	0	0	0	2112	2112	672	512	2208	2208	672	512	2112	1184	672	256	768	0	224	0	2208	1280	672	256	800	0	224	0
4.5	0	0	0	0	1664	1664	640	512	1888	1888	640	512	1664	896	640	256	608	0	224	0	1888	1056	640	256	672	0	224	0
4.75	0	0	0	0	1248	1248	608	512	1504	1504	608	512	1248	608	608	256	448	0	224	0	1504	800	608	256	544	0	224	0
5	0	0	0	0	896	896	576	512	1088	1088	576	512	896	384	576	224	320	0	192	0	1088	512	576	224	384	0	192	0
5.25	0	0	0	0	640	640	544	480	800	800	544	480	640	224	544	192	224	0	192	0	800	320	544	192	288	0	192	0
5.5	0	0	0	0	416	416	544	512	544	544	544	512	416	96	544	224	128	0	192	0	544	160	544	224	192	0	192	0
5.75	0	0	0	0	224	224	512	480	320	320	512	480	224	0	512	192	64	0	192	0	320	32	512	192	128	0	192	0
6	0	0	0	0	128	128	480	448	192	192	480	448	128	0	480	160	32	0	160	0	192	0	480	160	64	0	160	0
6.25	0	0	0	0	32	32	480	480	64	64	480	480	32	0	480	160	0	0	160	0	64	0	480	160	32	0	160	0
6.5	0	0	0	0	0	0	448	448	0	0	448	448	0	0	448	160	0	0	160	0	0	0	448	160	0	0	160	0
6.75	0	0	0	0	0	0	416	416	0	0	416	416	0	0	416	128	0	0	160	0	0	0	416	128	0	0	160	0
7	0	0	0	0	0	0	416	416	0	0	416	416	0	0	416	160	0	0	128	0	0	0	416	160	0	0	128	0

表3 ISDN，G.992.1 Annex.A/Cに対する干渉（隣接4回線）

距離	ISDN		G.992.1 (FDM)		G.992.2 AnnexA		G.992.1 AnnexC				G.992.2 AnnexC			
							DBM		FBM		DBM		FBM	
	DS	US	DS	US	DS	US	DS	US	DS	US	DS	US	DS	US
0.5	144	144	7104	832	3008	832	7104	832	2624	288	3008	832	1088	288
0.75	144	144	7104	832	3008	832	7104	832	2624	288	3008	832	1088	288
1	144	144	7104	832	3008	832	7104	832	2624	288	3008	832	1088	288
1.25	144	144	7104	832	3008	832	7104	832	2624	288	3008	832	1088	288
1.5	144	144	7104	832	3008	832	7104	832	2624	288	3008	832	1088	288
1.75	144	144	7104	832	3008	832	7104	832	2624	288	3008	832	1088	288
2	144	144	7008	832	3008	832	7008	832	2592	288	3008	832	1088	288
2.25	144	144	6752	832	3008	832	6752	832	2496	288	3008	832	1088	288
2.5	144	144	6560	832	3008	832	6560	832	2432	288	3008	832	1088	288
2.75	144	144	6144	800	2976	800	6144	800	2272	288	2976	800	1088	288
3	144	144	5536	800	2976	800	5536	800	2048	288	2976	800	1088	288
3.25	144	144	4704	800	2944	800	4704	800	1728	288	2944	800	1088	288
3.5	144	144	3904	768	2880	768	3904	768	1440	288	2880	768	1056	288
3.75	144	144	3264	768	2752	768	3264	768	1184	256	2752	768	1024	256
4	144	0	2688	736	2560	736	2688	736	992	256	2560	736	928	256
4.25	144	0	2208	704	2304	704	2208	704	800	256	2304	704	832	256
4.5	0	0	1760	672	1952	672	1760	672	640	256	1952	672	704	256
4.75	0	0	1344	640	1568	640	1344	640	480	224	1568	640	576	224
5	0	0	992	640	1184	640	992	640	352	224	1184	640	416	224
5.25	0	0	704	608	864	608	704	608	256	224	864	608	320	224
5.5	0	0	480	576	608	576	480	576	160	192	608	576	224	192
5.75	0	0	320	544	384	544	320	544	96	192	384	544	128	192
6	0	0	160	544	224	544	160	544	32	192	224	544	64	192
6.25	0	0	64	512	96	512	64	512	0	192	96	512	32	192
6.5	0	0	0	480	32	480	0	480	0	160	32	480	0	160
6.75	0	0	0	480	0	480	0	480	0	160	0	480	0	160
7	0	0	0	448	0	448	0	448	0	160	0	448	0	160

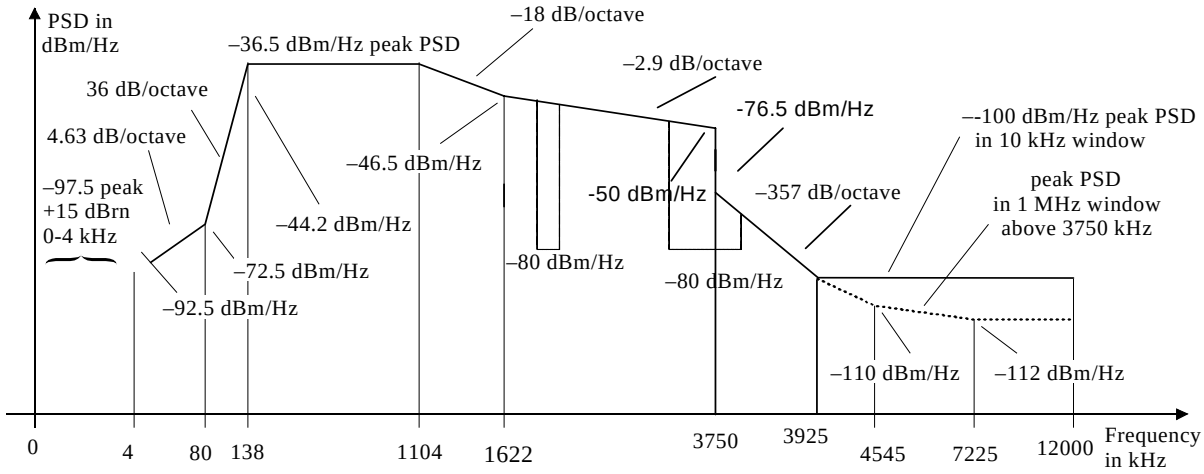
別紙

ATU-C Downstream transmit spectral mask for Annex.Q (draft)

The downstream spectral mask of Annex Q is as specified in this paper. Annex Q does not support overlapped spectrum. Therefore, C-MSG1 bit 16 shall be set to 0, and the PSD mask specified in § 1. shall be used.

1. Downstream non-overlapped PSD mask definition

The non-overlapped PSD mask is defined with absolute peak values in Figure 1. The low frequency stop band is defined for frequencies below 138 kHz (tone 32); the high frequency stop band is defined at frequencies greater than 3750 kHz (tone 869). The in-band region of this PSD mask is the frequency band from 138 kHz to 3750 kHz.



Frequency band f (kHz)	Equation for line (dBm/Hz)
0 < f < 4	-97.5
4 < f < 80	-92.5 + 4.63*log2(f/4)
80 < f < 138	-72.5 + 36*log2(f/80)
138 < f < 1104	-36.5
1104 < f < 1622	-36.5 - 18.0*log2(f/1104)
1622 < f < 3750	-46.5 - 2.9*log2(f/1622)
3750 < f < 3925	-76.5 - 357*log2(f/3750)
3925 < f < 12000	-100

G.992.1 Annex Q equipment shall be able to reduce the PSD below –80 dBm/Hz for the Amateur radio bands between 1.81 MHz and 2.00 MHz, and between 3.5 MHz and 3.8 MHz.

Frequency (kHz)	PSD level (dBm/Hz)	Measurement BW
0	-97.5	100 Hz
4	-97.5	100 Hz
4	-92.5	100 Hz
10	interpolated	10 kHz
80	-72.5	10 kHz
138	-44.2	10 kHz
138	-36.5	10 kHz
1104	-36.5	10 kHz
1622	-46.5	10 kHz
3750	-50	10 kHz
3750	-76.5	10 kHz
3925 – 12000	-100	10 kHz

Additionally the PSD mask shall satisfy the following requirements:

Frequency (kHz)	**PSD level (dBm/Hz)**	Measurement BW
3925	-100	1 MHz
4545	-110	1 MHz
7225	-112	1 MHz
12000	-112	1 MHz

NOTE 1 – All PSD measurements are in 100 Ω; the POTS band total power measurement is in 600 Ω.

NOTE 2 – The breakpoint frequencies and PSD values are exact; the indicated slopes are approximate. The breakpoints in the tables shall be connected by linear straight lines on a dB/log(f) plot.

NOTE 3 – MBW specifies the Measurement Bandwidth. The MBW specified for a certain breakpoint with frequency fi is applicable for all frequencies satisfying fi< f ≤ fj, where fj is the frequency of the next specified breakpoint.

NOTE 4 – The power in a 1 MHz sliding window is measured in a 1 MHz bandwidth, starting at the measurement frequency i.e. power in the [f, f + 1 MHz] window shall conform to the specification at frequency f.

NOTE 5 – The step in the PSD mask at 4 kHz is to protect V.90 performance. Originally, the PSD mask continued the 21 dB/octave slope below 4 kHz hitting a floor of –97.5 dBm/Hz at 3400 Hz. It was recognized that this might impact V.90 performance, and so the floor was extended to 4 kHz.

NOTE 6 – All PSD and power measurements shall be made at the U-C interface.

Figure 1: Non-overlapped Downstream Channel PSD Mask

Spectral Shaping of the In-Band Region defined in §2 and Transmit Signals with Limited Transmit Power defined in §3 shall be applied.

2. Spectral Shaping of the In-Band Region of the PSD Spectrum

In order to shape the ATU-C PSD, frequency dependent gains, called spectral shaping values (ssv_i), shall be applied on each tone during initialization and showtime. The ssv_i values shall be represented with 1 bit before and 10 bits after the decimal point.

Table 1 defines the corner points for the nominal PSD shape of the inband region as gain in dB, i.e log_ssv_i. Log_ssv_i on other tones shall be linearly interpolated between corner points on a logarithmic scale for the gain (dB) and a linear scale for the frequency (Hz). Note that the corner points defined in Table 1 are relative values.

The spectral shaping values shall be converted from logarithmic scale (log_ssv_i, dB values) to linear ssv_i values according to:

$$ssv_i = \frac{Round\left(1024 \times 10^{\frac{\log\_ssv_i}{20}}\right)}{1024}$$

These points are not passed at initialization for the nominal PSD shape but are provided here for reference. However, for additional spectral shaping (see §4), parameters are passed during G.994.1.

The combined accuracy of the process of linear interpolation of the log_ssvi values and the process of conversion to linear ssv_i values shall be strictly less than one half lsb of the 10 bit after the decimal point format of the linear ssvi values. No error shall be introduced when log_ssv_i equals 0dB or is interpolated between log_ssv_i values, which equal 0dB.

NOTE 1: The above definition ensures that the maximum deviation between ssv_i values used by transmitter and receiver is one lsb.

NOTE 2: The above needs an accuracy that is strictly < 1/2 lsb. An accuracy of = 1/2 lsb, will lead to inaccurate results.

Table 1: Corner points for the non-overlapped nominal in-band PSD shape.

Tone Index	Log_ssv$_i$ (dB)	Comments
32	0	138 kHz defines the beginning of the inband region. No shaping is applied in the low stop band.
256	0	1104 kHz
376	–10	1622 kHz (–10 = -50 - Nominal_PSD_lowband)
869	–13.5	3750 kHz (–13.5 = -53.5 - Nominal_PSD_lowband)

The absolute values of the transmit PSD are obtained by scaling the relative shaping values with a NOMINAL_PSD_lowband, defined for the lower in-band frequencies. Note that the nominal in-band transmit PSD is frequency dependent. The NOMINAL_PSD_lowband is –40 dBm/Hz (flat from 138 kHz to 1104 kHz) for the non-overlapped spectrum.

NOTE 3: In-band PSD spectral shaping is applied prior to the IFFT.

NOTE 4: The value of MAXNOMATPds may be limited by regional regulations.

3. Transmit Signals with Limited Transmit Power

For cases where the transmit signal must be limited to a maximum aggregate total power (e.g. ATP_{dsmax} = +20 dBm), then

a) During initialization the PSD transmit level is specified as an offset from the nominal value, i.e. (Nominal_PSD_lowband + ssvi – x – power cutback) dB, and all values of gi = 1 for the offset value x and power cutback. The value of x shall be the greater of 0 dB and (21.1 – ATPdsmax) dB. For ATPdsmax = 20 dBm, the corresponding value of x shall be 1.1 dB.

b) If bi>0, then valid range for gi is [-14.5 to +2.5+x] (dB) ;
If bi>0, then gi shall be in the [g_{sync} – 2.5 to g_{sync} + 2.5] (dB) range;
If bi=0, then gi shall be equal to 0 (linear) or in the [-14.5 to g_{sync}] (dB) range;
For G.992.1 annex Q, g_{sync} <= x dB

The g_i values shall be constrained by following relation:

Constraint on g_i values	$\sum_{i=6}^{511} ssv_i^{\,2} * g_i^{\,2} \le \sum_{i=6}^{511} ssv_i^{\,2}$

§4 Additional inband spectral shaping

An ATU-R may request additional downstream inband spectral shaping by passing parameters to the ATU-C in a G.994.1 CLR, MP, or MS message. The ATU-C may select additional downstream inband spectral shaping by passing parameters to the ATU-R in a G.994.1 CL or MS message. Within the framework of G.994.1, the ATU-C has the ability to make the final decision on the downstream inband PSD shape to be used.

The additional inband spectral shaping parameters are listed in G.992.1 Annex I 7.2.2 and defined in G.992.1 Annex I 7.3. If the Additional inband spectral shaping Spar(2) bit is set to ONE in G.992.1 Annex I Table I.6.2, its associated Npar(3) octets in Tables I.6.2.1 to I.6.2.1.5 define the inband spectral shape. If the additional inband spectral shaping Spar(2) bit is set to ZERO, its associated Npar(3) octets are not transmitted and the nominal inband PSD shape defined in §2 shall be used. These Npar(3) octets define the downstream PSD levels in the low band (between 138 and 1104 kHz), at 1622 kHz and at 3750 kHz. The PSD levels between 1104 kHz and 1622 kHz, and between 1622 kHz and 3750 kHz are linearly interpolated in log scale. The defined values are the PSD level in dB below the NOMINAL_PSD_lowband of –40dbm/Hz. For example, if all three values are set to 20 dB, the result will be a flat PSD of –60dbm/Hz. If the three values are set to 2 dB, 12 dB and 15.5 dB, the result is the PSD defined in §1 reduced by

2dB. In order not to violate the PSD mask defined in §1, the second value shall be no less than 10 dB and the third value shall be no less than 13.5 dB.

5. Egress control

G.992.1 Annex Q equipment shall be able to reduce the PSD below –80 dBm/Hz for the Amateur radio bands between 1.81 MHz and 2.00 MHz, and between 3.5 MHz and 3.8 MHz. The ATU-C may apply additional spectral shaping as described in §4 to help achieve this requirement.