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Question: 4/15

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TITLE: G.hs: Spectrum considerations for G.hs

ABSTRACT

This contribution begins with a review of the upstream and downstream PSD requirements of xDSL services co-mingled with POTS or ISDN services. Implications of the xDSL PSDs on the G.hs PSD are discussed. Spectrum allocation for G.hs signals as well as modulation parameters are proposed. Draft text for the Modulation and Activation section is proposed.

1. Introduction:

G.hs will be used to initiate or activate many types of existing and future xDSL services, therefore requirements from the various xDSL services should be carefully considered in the design of G.hs. This contribution addresses two inter-related considerations: spectrum and activation methods. For G.hs, suitable bands must be selected for transmission of the negotiation and user data channels. Those bands need to be selected with consideration to the existing overall PSDs of the xDSL services and also to the activation signals of existing xDSL services.

This contribution is organized as follows: Section 2 reviews the spectra of several xDSL services. Section 3 is a discussion of the spectra and assumptions. Section 5 contains specific proposals for G.hs draft text.

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This contribution addresses the these spectrum. modulation, and activation issues in WH-016R1:

Issue #	Status	Description	AB-026 section
2.2	Open	What spectrum(s) should be used by G.hs?	3.2
2.2.1	Agreed	min and max G.hs carriers	3.2
2.5	Open	How many bands should be used for G.hs negotiation?	3.2, 5.2
2.6	Open	What techniques should be used in TCM-ISDN environment?	3.2 low freq.
2.7	Open	Assuming multiple bands, should the transmission be serial, pre-configured, or parallel, or should the selection be automatic, based on sensing spectral energy on the line?	3.2, 5.3
2.7.1	Agreed	to add the following note to the text of G.hs: It is advised to monitor for existing services prior to transmitting signals to avoid interfering with them.	5.3
2.12	Agreed	to avoid the T1.413 - Issue 2 activation tones (R-ACT-REQ, C-ACTx, C-TONE) to allow an escape to that standard from G.hs (relates to item 1.4)	3.2, 5.2
2.12.1	Open	What other regional standard activation signals should be avoided?	3.4
3.2	Agreed	that G.hs shall use Differentially encoded binary Phase Shift Keyed (DPSK) modulation.	5.1
3.4.1	Agreed	that G.hs shall specify two families of signals, a 4kHz family and a 4.3125 kHz family	3.2, 5.2
3.4.2	Agreed	that different carrier frequencies shall be specified for transmission upstream and downstream.	3.2, 5.2
3.5	Agreed	that the 4 kHz family of signals shall achieve a data signalling rate of 800 bit/s, and the 4.3125 kHz family of signals shall achieve a data signalling rate of 539.0625 bit/s.	3.2, 5.25.2
3.10	Open	What carrier stability should be specified in G.hs	5.2
3.11	Agreed	that, no matter how many carriers are specified for a given signal (i.e., in a given band), all carriers shall be modulated simultaneously and shall carry the same information bits.	5.3
3.12	Agreed	that all of the DPSK signals used by G.hs shall be specified in G.hs, not in the associated xDSL Recommendations that G.hs supports.	5.2
3.13	Agreed	that a G.hs capable device shall respond in at least one of the bands in which it received a G.hs initiating signal. (If a G.hs capable device transmits in a given band, it shall be capable of receiving in at least the associated band).	5.3
3.14	Agreed	that the choice of signal family or a specific signal within a family does not affect the protocol information exchanged; e.g., a signal in the 4.0kHz family could be used to negotiate G.dmt Annex A.	Note 1 in 5.2
3.15	Agreed	that a G.hs capable device shall probe for the presence of another G.hs capable device by first transmitting unmodulated carriers from one or more signals. The response to this probe shall be unmodulated carriers from one or more corresponding signals. Modulation of the carriers shall then begin.	5.3
3.16	Agreed	that when a G.hs capable device detects initiating signals from more than one family, the response signal shall only be from one family	5.3
3.17	Agreed	that when a G.hs capable device transmits initiating signals from both families at the same time, one family shall be turned off upon detection of a response carrier and prior to carrier modulation …	5.3
3.18	Agreed	that, in order to facilitate finding a common signal (if one exists), a detecting modem that cannot respond in the appropriate signal family shall respond in the wrong family. ….	5.3
3.19	Agreed	to add the following note to the text of G.hs: It is encouraged to try sufficient signals to discover a common signal if one exists.	Note in 5.3
3.20	Agreed	to add the following note to the text of G.hs: It is encouraged that new xDSL services use existing signals in one of the two families.	Note 3 in 5.2

2. Preliminary Survey of Existing Spectra and Activation

Various spectra of xDSL and existing services that might be negotiated by G.hs are shown in Table 1 and are based on WH-120.

For the purposes of this contribution (and possibly later in G.hs) we indicate the "upstream" and "downstream" directions using the nomenclature from the various xDSL services in Table 2.

Table 3 lists some of the initiating activating sequences.

Table 1. Preliminary survey of existing spectra

Item	Modulation (Document)	Total Bandwidth		Upstream Bandwidth		Down Stream Bandwidth	
		Lower (kHz)	Upper (kHz)	Lower (kHz)	Upper (kHz)	Lower (kHz)	Upper (kHz)
P-1	G.dmt Annex A	26	1,104	26	138	26	1,104
P-1	G.lite Annex A (FDM)	26	1,104	26	138	26	1,104
I-2	G.dmt Annex B	138	1,104				
I-5	G.dmt Annex C	26	50	26	50	26	50
I-5	G.lite Annex C	26	50	26	50	26	50
H-5	HDSL2			0	400	0	900
V-1	VDSL (with European ISDN) DTS/TM-06003-1(draft) V0.0.7 (1998-2) Section 8.2 Frequency plan	300	30,000	300	30,000	300	30,000

Table 2. Definitions of Upstream and Downstream

Modulation (Document)	Upstream	Downstream
G.dmt	xTU-R → xTU-C	xTU-C → xTU-R
T1.413 Cat 1 w/ Analog filters	ATU-R → ATU-C	ATU-C → ATU-R
G.lite	xTU-R → xTU-C	xTU-C → xTU-R
DMT with only 64 tones	xTU-R → xTU-C	xTU-C → xTU-R
G.hdsl	NTU → LTU	LTU → NTU
HDSL2	NTU → LTU	LTU → NTU
VDSL (with European ISDN) DTS/TM-06003-1(draft) V0.0.7 (1998-2)	NT → ONU (LT)	ONU (LT) → NT-R
Notes: xTU-R, NTU, NT indicate customer side xTU-C, LTU, ONU indicate network side		

Table 3. Activation signals of existing xDSLs

Modulation (Document)	Initiator	Responder	Reference
G.dmt	None - will use G.hs		
G.lite	None - will use G.hs		
T1.413 Issue 1	R-ACT-REQ 34.5 kHz (#8) sinusoid with cadence of: 128 symbols on 64 symbol @ –2 dBm (~16ms) 64 symbol @ –22 dBm (~16ms) 896 symbols off (~221ms)	C-ACT1 207 kHz (#48) C-ACT2 190 kHz (#44 C-ACT3 224 kHz (#52) C-ACT4 259 kHz (#60)	Issue#1 - 12.3.1
T1.413 Issue 2	(same as Issue 1)	(same as issue 1)	Issue #2 Section 9.3.1
ETSI: ADSL over ISDN	same as T1.413 but k=42; 181.125 kHz	C-ACT2m 319 kHz (#74) C-ACT2e 328 kHz (#76)	
RADSL CAP	RTU-R transmits RSO+trailer (pseudo noise at symbol rate) Using 68kHz and 85 kHz	Using 282 kHz and 306 kHz	
G.hdsl (2B1Q)	LTU transmits S0	NTU transmits S0	Figure 11,Section 5.6, draft G.hdsl (TD-38)
G.hdsl (CAP - Annex B)	LTU transmits CS0 3150 symbols of pseudo noise at symbol rate	NTU transmits RS0 3150 symbols of pseudo noise at symbol rate	Section B.5.6
HDSL2	??		
VDSL DTS/TM-06003-1(draft)			Not defined yet

3. Proposals for G.hs Spectrum and Activation

3.1 Either terminal initialization

A terminal must known if it is an xTU-C or xTU-R to correctly assign the upstream and downstream roles (i.e., which tones it can transmit)

3.2 Carrier Selection criteria and proposal

In the selection of G.hs carriers, the following criteria shall be met:

1. Considers all of the services/families known today (Annex A, Annex B, Annex C, HDSL2) (For VDSL, see section 3.4)
2. Upstream and downstream will not use the same frequencies (i.e., G.hs does not use echo canceling)
3. FDM filter implementations (with a few nonessential additions) - i.e., avoid upstream/downstream interleaving
4. Avoid existing T1.413 activation tones (8, 44, 48, 52, 60) (as per G.hs agreement 2.12)
5. G.dmt Annex A and G.lite Annex A use same carriers. G.dmt Annex C and G.lite Annex C use same carriers. (For both upstream and downstream)
6. At least one carrier of G.dmt Annex A is same as that of G.dmt Annex C. At least one carrier of G.lite Annex A is same as that of G.lite Annex C. (for both upstream and downstream)
7. The ADSL Annex A Downstream band is reduced to tone 37 through 68 based on the G.lite agreement 27.19
8. Reasonably robust against Intermodulation products
9. A grid for decimation (mainly applicable for Annex A and Annex B)
10. Higher frequency tones should be spaced farther apart to reduce leakage in filters
11. In general, 3 tones per Annex (Annex C has 2 primary tones each way, and a third borderline tone)
12. Tones between 14 and 64 should not be transmitted into a TCM-ISDN environment.
13. Avoid (if possible) RADSL activation frequencies. Upstream 68kHz (~#16) and 85kHz (~#20). Downstream 282kHz (~#65) and 306kHz (~#71).

A set of conforming carriers is:

Upstream (grid = 4N+1) 9 11 13 21 33 37 41

Downstream (grid = 8N+2)6 7 (26) 50 58 66 74 90 114

Tone area 2-5 reserved for 4k family

The proposal is graphically illustrated in Table 4.

Table 4. G.hs Carrier Proposal

	Up	Down	Upstream	Downstream
Up- Avoids			8 16, 20	65 71
HDSL2	(2-3)			
Anx. A			9 13 21	
Anx. B			33 37 41	
Anx. C			9 11 13	
Dn - Avoids				44 48 52 60 ?-Note 7
HDSL2		(4-5)		
Anx. A			*26	50 58 66
Anx. B			Note 6	74 90 114
Anx. C		6 7		66 74

Index	2,3	4,5	6	7	8	9	11	13	16, 20	21	26	31	33	37	41	44	48	50	52	58	60	63	65	66	68	71	74	90	114	255
Up -HDSL2	2			7																									
Anx. A				7								31																	
Anx. B													33									63							
Anx. C			6					13																					
Dn - HDSL2	2			7																									
Anx. A													33												68				
Anx. B																							65						255
Anx. C			6					13																					

Comments:

1. Upstream and downstream carriers are completely separated.
2. The upstream and downstream bands of the existing T1.413 activation tones are preserved.
3. Although the committee approached the allocation of carriers by suggesting that each annex would have it's own set of carriers forming a single signal, the allocation of the carriers allows some carriers to be shared by more that one Annex. Thus the concept of signals is not so useful. Further, Annex B allows optional use of tones below 33 in which the ATU-x may be able to use some but not all of the carriers originally designated for Annex A.
4. Annex B upstream band and Annex A downstream band essentially overlap so the common band was divided between the two requirements.
5. The tones associated with Annex A and B are set along a common grid.
6. * Tone 26 may optionally be used for downstream transmission so that a much lower frequency could be used in cases of high frequency line attenuation. However since it is in the midst of the upstream band, filter implementations may preclude it's usage.
7. Tone 74 falls in the null of TCM-ISDN spectrum so there is some positive SNR there and it is in common with Annex B.
8. Tone 74 was selected as the frequency for Annex B's C-ACT2m, but I do not think it has been deployed yet.
9. The band to allocate Annex B upstream tones is very narrow. Using 3 carriers places the two outer carriers very near the band edge. If 2 carriers are sufficient, they could have much better placement. In that case, the appropriate upstream grid is 4N-1 and all of the revised upstream carrier values are shown in Table 5.

Table 5. Modified G.hs Carrier Proposal

		Down		Upstream											Downstream												
UP	Avoids			8				16	20																	
	HDSL2																									
	Anx. A					11	15			23																
	Anx. B												35		39											
	Anx. C				9	11																				
Index		6	7	8	9	11	15	16	20	23	26	31	35		39	44	48	50	52	58	60	63	66	68	74	90	114	255

Neither Table 4 nor Table 5 would appear in G.hs

Table 6. Modified G.hs Carrier Proposal (Upstream grid = 3)

		Down		Upstream											Downstream												
UP	Avoids			8				16	20																	
	HDSL2																									
	Anx. A				9	12				21	27															
	Anx. B											33	36		39											
	Anx. C				9	12																				
Index		6	7	8	9	12	15	16	20	21	27	33	36		39	44	48	50	52	58	60	63	66	68	74	90	114	255

3.3 Reduction of Carriers

There has been some interest expressed in reducing the number of carriers being used once communication has been established. The difficulty is for the transmitter to know which tones the receiver is actually receiving. Of the several proposals presented here, we recommend the last one. Text implement the last proposal is included in below.

3.3.1 Default Proposal:

Just transmit everything, do not attempt reduction of carriers.

3.3.2 Pair phase reversal proposal:

The upstream and downstream tones are paired. If an xTU-x is receiving a tone from a particular pair it can transmit phase reversals on it's corresponding mate before beginning modulated carrier.
Limitations:

- One of the mates might not be usable because of bridge taps or interference.
- The currently proposed carriers cannot be uniquely paired easily

3.3.3 Modulate carriers before messages Proposal:

After sending unmodulated carrier and before sending modulated carrier messages beginning with flags, the xTU-X modulates all of it's carriers encoded to indicate which carriers it is receiving. Codes could be created by transmitting concatenated 50% duty cycle patterns of 1, 0 with different lengths indicating the different carriers. The fixed duty cycle allows reception without octet synchronization.
Limitations:

- Not very bit or time efficient
- Might as well octet synchronize first and send the information in a G.hs message
- Introduces an extra turn around
- Coding does not include error correction.

3.3.4 Carriers used and Request Transmit in messages Proposal:

Use all possible carriers during CL/CLR messages. Using parameters in CL/CLR messages, negotiate which carriers to use for MS/MR/ACK/NACK messages onward in the same transaction or subsequent initializations beginning with MS or MR messages.. This would also imply that some memory would be needed between initializations (which is also implied by the use of MS messages initiated transactions).

If an interferer (or bridge tap) pops up later, a initialization timeout would allow all of the possible tones to be used from the initiating xTU-X.

3.4 VDSL Requirements.

In the above carrier selection proposals, we attempt to examine several xDSL requirements simultaneously. It is also prudent to be aware of the ongoing work in VDSL. We consider some preliminary criteria and considerations for selecting G.hs carriers for use with VDSL devices:

- Some VDSL splitter designs would begin the HPF rolloff around 600 kHz, thus some G.hs carriers should be above 600 kHz. (ADSL tone #140). Other will rolloff at 300 kHz (ADSL tone #70)
- Although there is discussion of a ADSL-compatible mode of VDSL which ensures no interference to ADSL lines in the same binder by significantly reducing power in carriers below 1.1 MHz, a VDSL devices could transmit G.hs carriers in compliance with the ADSL PSDs. Care should be taken not to introduce performance degradation to existing services, in particular ADSL.
- The current VDSL proposal calls for carriers spaced at 21.625 and 43.125 kHz however it is likely that devices will initiate in 43.125 kHz mode, so a G.hs carriers with a grid of 43.125 kHz is preferred.
- The carriers should be below 3 MHz (equivalent ADSL tone #695) so that they can be detected on the longest of VDSL capable lines.
- The carriers should avoid known HAM radio bands. 1.8-2.0 MHz (equivalent ADSL tone #417 - #464) in North America. 1.81 - 2.0 MHz in Europe.
- Should consider interference from AM radio stations.
- VDSL will employ TDD techniques, so upstream and downstream separation need not be so strict.
- Signals above 1.1 MHz in the VDSL band should be transmitted in synchrony with the ONU's chosen superframe structure to avoid NEXT into the other TDD VDSL lines in the binder.
- At least one set of carriers inside the VDSL plan.

Conforming tones:

Downstream Grid = (ADSL downstream grid) x (VDSL grid) = (8N+2) x (10)
→ 100, 180, 260, 340, etc

Upstream Grid = (ADSL upstream grid) x (VDSL grid) = (4N-1) x (10)
→ 350, 390, 470, 510, 550, etc

4. Text to be added to G.hs is in Section 5

This following section presents text to be added to G.hs that encompasses the proposal described above.
Some text on DPSK was adapted from ITU-T Recommendation V.34 The suggested text should be inserted as a new section between existing sections 5 and 6. Existing section 6 and onward should be renumbered.

5. Modulation and Activation

5.1 Modulation method

All messages in G.hs are sent with one or more carriers using Differential Binary Phase Shift Keying (DPSK) modulation. The transmit point is rotated 180 degrees from the previous point if the transmit bit is a 1, and the transmit point is rotated 0 degrees from the previous point if the transmit bit is a 0. Each message is preceded by a point at an arbitrary carrier phase.

5.2 Carriers

Carriers shall be selected from two families of carriers based on multiples of 4.3125 kHz or 4.0 kHz. The 4.0kHz family, designated family B, achieves a bit rate of 800 bits/s. The 4.3125kHz family, designated family A, achieves a bit rate of 539.0625 bits/s by dividing the 4312.5 symbols/sec rate by 8. The specific carrier frequencies are specified in Table 7 and have a tolerance of +/- 0.01%.

Table 7. Carriers

Upstream / Downstream	Family	Label	Frequency (kHz)	
Upstream	A (4.3125 kHz)	A_{U01}	38.8125	(9 x)
		A_{U02}	47.4375	(11 x)
		A_{U03}	56.0625	(13 x)
		A_{U04}	90.5625	(21 x)
		A_{U05}	142.3125	(33 x)
		A_{U06}	159.5625	(37 x)
		A_{U07}	176.8125	(41 x)
	B (4.000 kHz)	B_{U01}	8.000	(2 x)
		B_{U02}	12.000	(3 x)
Downstream	A (4.3125 kHz)	A_{D01}	25.8750	(6 x)
		A_{D02}	30.1875	(7 x)
		A_{D03}	215.6250	(50 x)
		A_{D04}	250.1250	(58 x)
		A_{D05}	284.6250	(66 x)
		A_{D06}	319.1250	(74 x)
		A_{D07}	288.1250	(90 x)
		A_{D08}	491.6250	(114 x)
Downstream	B (4.000 kHz)	B_{D01}	16.000	(4 x)
		B_{D02}	20.000	(5 x)

NOTE 1 - The choice of signal family or a specific carrier within a family does not effect the protocol information exchanged. E.g., 4.0kHz could be used to negotiate a service utilizing 4.3125kHz carriers.

NOTE 2 - It is highly desirable to design linear phase transmitter channel separation and shaping filters since there are no provisions for adaptive equalizer training.

NOTE 3 - Future xDSL services are encouraged to use existing carriers selected from Table 7.

5.3 Initialization

5.3.1 Initiation by an xTU-R.

The initiating xTU-R shall transmit unmodulated carriers selected from either one or both families of the Upstream group in Table 7. After receiving the carriers from the xTU-R for at least 200ms, the responding xTU-C shall transmit unmodulated carriers selected from only one family of the Downstream group in Table 7. After receiving the carriers from the xTU-C for at least 200ms, the xTU-R shall modulate only one of the family of carriers with DPSK and shall transmit Flags (0x7E) as the data. If the xTU-R initiated with carriers selected from both families,

the xTU-R shall stop transmitting carriers from the other family before it begins modulating carriers from the selected family. After receiving flags from the xTU-R, the xTU-C modulate only one of the family of carriers with DPSK and shall transmit Flags (0x7E) as the data.

To facilitate finding a common set of carriers (if they exist), if an xTU-C receives carriers of a family that it cannot transmit, it shall nevertheless respond by transmitting carriers from a family it is capable of transmitting. This allows the xTU-R to detect presence of the xTU-C and attempt initiating with a different carrier family if it has the capability to do so.

The xTU-C and the xTU-R shall monitor the line for existing services prior to transmitting carriers to avoid interfering into existing services.

The xTU-C shall transmit identical data with identical timing on any and all downstream carriers. The xTU-R shall transmit identical data with identical timing on any and all upstream carriers.

NOTE - The xTU-R and xTU-C are encouraged to transmit as many carriers as possible to allow discovery of common carriers if they exist.

5.3.2 Initiation by an xTU-C

The initiating xTU-C shall transmit unmodulated carriers selected from either one or both families of the Downstream group in Table 7. After receiving the carriers from the xTU-C for at least 200ms, the responding xTU-R shall transmit unmodulated carriers selected from only one family of the Upstream group in Table 7. After receiving the carriers from the xTU-R for at least 200ms, the xTU-C shall modulate only one of the family of carriers with DPSK and shall transmit Ones(0xFF) as the data. If the xTU-C initiated with carriers selected from both families, the xTU-C shall stop transmitting carriers from the other family before it begins modulating carriers from the selected family. After receiving Ones from the xTU-C, the xTU-R modulate only one of the family of carriers with DPSK and shall transmit Flags (0x7E) as the data. After receiving flags from the xTU-R, the xTU-C modulate only one of the family of carriers with DPSK and shall transmit Flags (0x7E) as the data.

To facilitate finding a common set of carriers (if they exist), if an xTU-R receives carriers of a family that it cannot transmit, it shall nevertheless respond by transmitting carriers from a family it is capable of transmitting. This allows the xTU-C to detect presence of the xTU-R and attempt initiating with a different carrier family if it has the capability to do so.

The xTU-C and the xTU-R shall monitor the line for existing services prior to transmitting carriers to avoid interfering into existing services.

The xTU-C shall transmit identical data with identical timing on any and all downstream carriers. The xTU-R shall transmit identical data with identical timing on any and all upstream carriers.

NOTE - The xTU-R and xTU-C are encouraged to transmit as many carriers as possible to allow discovery of common carriers if they exist.

5.3.3 Error Recovery

The transmission of unmodulated carrier, Ones (0xFF), or Flags (0x7E) shall not exceed 1 second. An xTU-x may restart initiation or may optionally start alternative initiation procedures.

5.4 PSD

The PSD of the transmitted carriers shall conform to the relevant PSD specification for that band.

6. Summary:

1. Agenda Item: G.hs spectrum, activation

2. Expectations:
   - Agree to the carrier selection criteria in 3.2
   - Agree to the specific carriers proposed in 3.2
   - Adopt text in section 5 as working text

3. New issues to be added:

G.hs Issues Section	Issue	Proposed Answer
2.12.1	What other regional standards should be considered?	Consider VDSL as discussed in 3.4
2	What carrier reduction techniques shall be used?	None (3.3.1) or the proposal in 3.3.4

4. Proposals for open issues and draft text for agreements:
   See complete reference table in the Introduction.