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Amendment 4

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ITU-T Recommendation G.992.3

Asymmetric digital subscriber line transceivers 2 (ADSL2)

Amendment 4

Accuracy of test parameters

Summary

This amendment contains text for further amendments to ITU-T Recommendation G.992.3.

The following items are included in this amendment:

- Accuracy of test parameters (new clause 8.12.5 and new Appendix VIII).
- Annex C amendments.

Source

Amendment 4 to ITU-T Recommendation G.992.3 (2005) was approved on 29 July 2007 by ITU-T Study Group 15 (2005-2008) under the ITU-T Recommendation A.8 procedure.

FOREWORD

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ITU-T Recommendation G.992.3

Asymmetric digital subscriber line transceivers 2 (ADSL2)

Amendment 4

Accuracy of test parameters

Replace clause 8.12.5 (contained in G.992.3 Amendment 3) to this Recommendation by the following text.

8.12.5 Accuracy of test parameters

This clause defines accuracy requirements for test parameters defined in clause 8.12.3. The accuracy requirements are expressed as a tolerance relative to a reference value. Both the reference value and the allowed tolerance are defined in this clause.

The accuracy requirements of test parameters are optional. An ATU may comply to the accuracy requirements for all or a subset of the test parameters.

NOTE – The measurement of test parameter reference values involves the use of test equipment. The accuracy requirements defined in this clause do not take into account test equipment tolerance. Test equipment tolerance is out of the scope of this Recommendation and is to be added to the tolerances defined in this clause.

8.12.5.1 Channel characteristics function per subcarrier (CCF-ps)

8.12.5.1.1 Channel attenuation in logarithmic format (HLOGps)

The downstream HLOGps reference value shall be defined for each subcarrier as follows:

$$HLOGps\_reference\_ds(i) = PSDps\_UR2(i) - (REFPSDds + log\_tssi(i))$$

where PSDps_UR2(i) is the downstream PSD measured at the U-R2 reference point, after initialization of the line up to a C-REVERB state, in which state the ATU-C is frozen and the ATU-R subsequently replaced by an RN = 100 Ω.

The upstream HLOGps reference value shall be defined for each subcarrier as follows:

$$HLOGps\_reference\_us(i) = PSDps\_UC2(i) - (REFPSDus + log\_tssi(i))$$

where PSDps_UC2(i) is the upstream PSD measured at the U-C2 reference point, after initialization of the line up to an R-REVERB state, in which state the ATU-R is frozen and the ATU-C subsequently replaced by an RN = 100 Ω.

NOTE 1 – The feature to freeze an ATU in a REVERB state exists solely to allow a test bed to be constructed for the purpose of measuring the HLOGps reference value. It applies only to specific transceivers serving as the "transmit transceiver" of the test environment, and is not a requirement for compliance to this Recommendation.

The receiving ATU shall measure the HLOGps values under the same loop, noise, temperature and configuration settings as are used for measuring the HLOGps reference values.

The HLOGps accuracy requirements shall apply only to those subcarriers with an SNR (as defined in clause 8.12.3.3) ≥ 12 dB, where the SNR is the SNR value measured during initialization.

The accuracy requirements for the downstream HLOGps (HLOGps_ds) shall apply only to the following subcarriers (with the corresponding frequency ranges being a part of the passband), and only if not within the downstream BLACKOUTset (see clause 8.13.2.4):

- Annexes A and I — Subcarriers 46 to 208
- Annex L — Subcarriers 46 to 104
- Annexes B, J and M — Subcarriers 92 to 208

The accuracy requirements for upstream HLOGps (HLOGps_us) shall apply to the subcarriers within the following frequency ranges (defined as a part of the passband), and not within the upstream BLACKOUTset (see clause 8.13.2.4):

- Annexes A and I — Subcarriers 11 to 23
- Annex L (mask 1) — Subcarriers 11 to 17
- Annex B — Subcarriers 36 to 53
- Annexes J and M — Subcarriers 11 to 53

Accuracy requirements outside these frequency ranges are for further study. Even though no accuracy requirements are specified outside the above frequency ranges, HLOGps measurements shall still be made and reported for all subcarriers as required in clause 8.12.3.1.

NOTE 2 – Having such specified ranges for accuracy requirements avoids variations due to the tolerances and effects of the filtering at the low ends of the passband and of the effects of folding at the high end of the passband.

The accuracy requirements for the downstream HLOGps (HLOGps_ds and HLOGps_us) shall apply only for those frequencies where the loop impedance (Z_{loop}) falls within the following ranges:

- impedance magnitude is between 100 Ω and 120 Ω;
- impedance imaginary component is between –20 Ω and 0 Ω.

The loop impedance (Z_{loop}) is defined as the impedance seen by the transceiver under test, looking into the loop, including the transmitting transceiver connected to the loop at the far end.

Accuracy requirements for HLOGps_ds and HLOGps_us, for frequencies where the loop impedance (Z_{loop}) falls outside this range, are for further study.

NOTE 3 – Appendix VIII provides an informative discussion of the effects on the accuracy of HLOG measurements caused by impedance mismatch between a nominal 100 Ω termination of the loop and possible termination impedances (Z_{ATU}) actually provided by a transceiver.

For each subcarrier where the HLOGps_ds accuracy requirement applies (based on its subcarrier index and SNRps_ds value only, and not considering restrictions related to its Z_{loop} value), and where HLOGps_reference_ds is above –90 dB, an HLOGps_ds value different from the special value defined in clause 8.12.3.1 shall be reported.

For each subcarrier where the HLOGps_ds accuracy requirement applies, and where HLOGps_reference_ds is above –90 dB, the absolute error (between the HLOGps_ds and the HLOGps_reference_ds) shall be equal to or smaller than 3.0 dB.

Requirements for the mean absolute error of HLOGps_ds reported values are for further study.

Accuracy requirements related to the difference over adjacent subcarriers of the absolute error (between the HLOGps_ds and the HLOGps_reference_ds) are for further study.

The HLOGps_ds accuracy requirements shall apply to HLOGps_ds measured in either initialization or in diagnostic mode.

For each subcarrier where the HLOGps_us accuracy requirement applies (based on its subcarrier index and SNRps_us value only, and not considering restrictions related to its Z_{loop} value), and where HLOGps_reference_us is above –90 dB, an HLOGps_us value different from the special value defined in clause 8.12.3.1 shall be reported.

For each subcarrier where the HLOGps_us accuracy requirement applies, and where HLOGps_reference_us is above –90 dB, the absolute error (between the HLOGps_us and the HLOGps_reference_us) shall be equal to or smaller than 3.0 dB.

Requirements for the mean absolute error of HLOGps_us reported values are for further study.

Accuracy requirements related to the difference over adjacent subcarriers of the absolute error (between the HLOGps_us and the HLOGps_reference_us) are for further study.

The HLOGps_us accuracy requirements shall apply to HLOGps_us measured in either initialization or in diagnostic mode.

8.12.5.1.2 Channel attenuation in complex format (HLINps)

The HLINps reference value and HLINps accuracy requirements are for further study.

8.12.5.2 Quiet line noise PSD per subcarrier (QLNps)

The downstream QLNps reference value shall be defined for each subcarrier as follows:

$$QLNps\_reference\_ds(i) = PSDps\_UR2(i)$$

where PSDps_UR2(i) is the downstream PSD measured at the U-R2 reference point, after initialization of the line up to a C-QUIET state, in which state the ATU-C is frozen and the ATU-R subsequently replaced by an RN = 100 Ω.

The upstream QLNps reference value shall be defined for each subcarrier as follows:

$$QLNps\_reference\_us(i) = PSDps\_UC2(i)$$

where PSDps_UC2(i) is the upstream PSD measured at the U-C2 reference point, after initialization of the line up to an R-QUIET state, in which state the ATU-R is frozen and the ATU-C subsequently replaced by an RN = 100 Ω.

NOTE 1 – The feature to freeze an ATU in a QUIET state exists solely to allow a test bed to be constructed for the purpose of measuring the QLNps reference value. It applies only to specific transceivers serving as the "transmit transceiver" of the test environment, and is not a requirement for compliance to this Recommendation.

The receiving ATU shall measure the QLNps values under the same loop, noise, temperature and configuration settings as are used for measuring the QLNps reference values.

The accuracy requirements for the downstream QLNps (QLNps_ds) shall apply to the subcarriers in the same frequency bands and with the same loop impedance (Z_{loop}) restrictions as where the HLOGps_ds accuracy requirements apply (see clause 8.12.5.1).

The accuracy requirements for upstream QLNps (QLNps_us) shall apply to the subcarriers in the same frequency bands and with the same loop impedance (Z_{loop}) restrictions as where the HLOGps_us accuracy requirements apply (see clause 8.12.5.1).

Accuracy requirements outside these frequency ranges are for further study. Even though no accuracy requirements are specified outside the above frequency ranges, QLNps measurements shall still be made and reported for all subcarriers as required in clause 8.12.3.1.

NOTE 2 – Having such specified ranges for accuracy requirements avoids variations due to the tolerances and effects of the filtering at the low ends of the passband and of the effects of folding at the high end of the passband.

For each subcarrier where the QLNps_ds accuracy requirement applies (based on its subcarrier index only, and not considering restrictions related to its Z_{loop} value), and where QLNps_reference_ds is above –130 dBm/Hz, a QLNps_ds value different from the special value defined in clause 8.12.3.2 shall be reported.

For each subcarrier where the QLNps_ds accuracy requirement applies, and where QLNps_reference_ds is above –130 dBm/Hz, the absolute error (between the QLNps_ds and the QLNps_reference_ds) shall be equal to or smaller than 3.0 dB. To account for sinusoidal noise sources internal to the ATU-R, this requirement does not apply to up to 5 groups of 3 adjacent subcarriers, which can selected at the ATU-R vendor's discretion.

The QLNps_ds accuracy requirements shall apply to QLNps_ds measured in either initialization or in diagnostic mode.

For each subcarrier where the QLNps_us accuracy requirement applies (based on its subcarrier index only, and not considering restrictions related to its Z_{loop} value), and where QLNps_reference_us is above –110 dBm/Hz, a QLNps_us value different from the special value defined in clause 8.12.3.2 shall be reported.

For each subcarrier where the QLNps_us accuracy requirement applies, and where QLNps_reference_us is above –110 dBm/Hz, the absolute error (between the QLNps_us and the QLNps_reference_us) shall be equal to or smaller than 3.0 dB.

The QLNps_us accuracy requirements shall apply to QLNps_us measured in either initialization or in diagnostic mode.

8.12.5.3 Signal-to-noise ratio per subcarrier (SNRps)

Noise PSD changes over time shall be reflected in the reported SNRps. This clause defines accuracy requirements for the change in SNRps over a time interval [T1,T2], relative to a reference value. The downstream and upstream reference values are defined as:

$$\Delta\text{SNRps\_reference\_ds}(i) = \text{Noise\_PSDps\_UR2\_T1}(i) - \text{Noise\_PSDps\_UR2\_T2}(i)$$

$$\Delta\text{SNRps\_reference\_us}(i) = \text{Noise\_PSDps\_UC2\_T1}(i) - \text{Noise\_PSDps\_UC2\_T2}(i)$$

where:

- Noise_PSDps_UR2_T1 is the stationary noise PSD (in dBm/Hz) present on the line at the U-R2 reference point at time instant T1, and for at least one minute before T1.
- Noise_PSDps_UR2_T2 is the stationary noise PSD (in dBm/Hz) present on the line at the U-R2 reference point at time instant T2, and for at least one minute before T2.
- Noise_PSDps_UC2_T1 is the stationary noise PSD (in dBm/Hz) present on the line at the U-C2 reference point at time instant T1, and for at least one minute before T1.
- Noise_PSDps_UC2_T2 is the stationary noise PSD (in dBm/Hz) present on the line at the U-C2 reference point at time instant T2, and for at least one minute before T2.
- These four Noise_PSDps are measured by the same method as is used to measure the QLNps_reference (see clause 8.12.5.2).

The receiving ATU shall measure the SNRps values under the same loop, noise, temperature and configuration settings as are used for measuring the SNRps reference values.

The SNRps_ds accuracy requirements shall apply to those subcarriers in the downstream passband where all of the following conditions hold:

- subcarrier is at least 50 kHz away from the lower and higher passband edges;
- bi_T1(i) > 0 and bi_T2(i) > 0;

- Noise_PSDps_UR2_T1(i) and Noise_PSDps_UR2_T2(i) are larger than –120 dBm/Hz;
- (SNRps_T1 – gi_T1) and (SNRps_T2 – gi_T2) are both smaller than 40 dB;

where:

- gi_T1(i) and gi_T2(i) are the downstream fine gains (in dB) at time instants T1 and T2;
- bi_T1(i) and bi_T2(i) are the downstream bitloadings at time instants T1 and T2;
- SNRps_T1(i) and SNRps_T2(i) are the downstream SNRps (in dBm), measured during showtime, at time instants T1 and T2.

The SNRps_us accuracy requirements shall apply to those subcarriers in the upstream passband where all of the following conditions hold:

- subcarrier is at least 50 kHz away from the lower and higher passband edge;
- bi_T1(i) > 0 and bi_T2(i) > 0;
- Noise_PSDps_UC2_T1(i) and Noise_PSDps_UC2_T2(i) are larger than –100 dBm/Hz;
- (SNRps_T1 – gi_T1) and (SNRps_T2 – gi_T2) are both smaller than 40 dB;

where:

- gi_T1(i) and gi_T2(i) are the upstream fine gains (in dB) at time instants T1 and T2;
- bi_T1(i) and bi_T2(i) are the upstream bitloadings at time instants T1 and T2;
- SNRps_T1(i) and SNRps_T2(i) are the upstream SNRps (in dBm), measured during showtime, at time instants T1 and T2, where the line does not reinitialize over the time period T1 to T2.

If the line does not reinitialize over a time period T1 to T2, the following accuracy requirements shall be met for downstream subcarriers where the SNRps_ds accuracy requirement applies:

$$|(SNRps\_T2(i) - gi\_T2(i)) - (SNRps\_T1(i) - gi\_T1(i)) - \Delta SNRps\_reference\_ds(i)| \leq 0.8 \text{ dB}$$

Accuracy requirements for downstream subcarriers where (SNRps_T1 – gi_T1) or (SNRps_T2 – gi_T2) is greater than 40 dB, are for further study.

For each downstream subcarrier where the SNRps_ds accuracy requirement applies, the statistical sample variance of SNRps_ds measurements (all samples taken over a 10-minute time interval, without line re-initialization in this time interval, and under the same loop, noise, temperature and configuration settings) shall be equal to or smaller than 0.5 dB.

If the line does not reinitialize over a time period T1 to T2, the following accuracy requirements shall be met for upstream subcarriers where the SNRps_us accuracy requirement applies:

$$|(SNRps\_T2(i) - gi\_T2(i)) - (SNRps\_T1(i) - gi\_T1(i)) - \Delta SNRps\_reference\_us(i)| \leq 0.8 \text{ dB}$$

Accuracy requirements for upstream subcarriers where (SNRps_T1 – gi_T1) or (SNRps_T2 – gi_T2) is greater than 40 dB, are for further study.

For each upstream subcarrier where the SNRps_us accuracy requirement applies, the statistical sample variance of SNRps_us measurements (all samples taken over a 10-minute time interval, without line re-initialization in this time interval, and under the same loop, noise, temperature and configuration settings) shall be equal to or smaller than 0.5 dB.

NOTE – In verification tests, noise changes should be applied gradually over time, and not simultaneously at the U-C2 and U-R2 reference point, so as not to force a re-initialization of the line.

8.12.5.4 Loop attenuation (*LATN*)

For further study.

8.12.5.5 Signal attenuation (*SATN*)

For further study.

8.12.5.6 Signal-to-noise ratio margin (*SNRM*)

For further study.

8.12.5.7 Attainable net data rate (*ATTNDR*)

For further study.

8.12.5.8 Actual aggregate transmit power (*ACTATP*)

The ATU-C near-end ACTATP reference value shall be defined as follows:

ACTATP_reference_UC2(i) = sum_over_all_frequencies [PSDps_UC2(i)]

where PSDps_UC2(i) is the downstream PSD measured at the U-C2 reference point, after initialization of the line up to the SHOWTIME state, in which state the ATU-C is frozen and the ATU-C subsequently connected to an RN = 100 Ω.

The ATU-R near-end ACTATP reference value shall be defined as follows:

ACTATP_reference_UR2(i) = sum_over_all_frequencies [PSDps_UR2(i)]

where PSDps_UR2(i) is the upstream PSD measured at the U-R2 reference point, after initialization of the line up to the SHOWTIME state, in which state the ATU-R is frozen and the ATU-R subsequently connected to an RN = 100 Ω.

NOTE 1 – The ACTATP should be measured first. Subsequently, the ATU should be frozen in showtime and the PSDps_Ux should then be measured without re-initialization.

NOTE 2 – The measurement of the PSDps_Ux involves freezing in showtime of the transceiver under test. Specification of special test modes for the transceiver under test is outside the scope of this Recommendation.

The absolute error between the ATU-C near-end ACTATP_ds and the ACTATP_reference_UC2 shall be equal to or smaller than 1.0 dB.

The absolute error between the ATU-R near-end ACTATP_us and the ACTATP_reference_UR2 shall be equal to or smaller than 1.0 dB.

Change the final line of clause 9.5.3.1 as follows:

4) When the ATU-C observes the stopped transmission, it also stops transmitting.

Annex C

Change clause C.7.10.3 as follows:

C.7.10.3 Exchange phase (replaces clause 7.10.3)

•••

The method used by the receiver to select these values is implementation-dependent. However, within the limit of the raw data rate and coding gain provided by the local PMD, the selected values shall meet all of the constraints communicated by the transmitter prior to the exchange phase, including:

- (message-based) Overhead data rate ≥ Minimum overhead data rate;
- net data rate ≥ minimum net data rate for all bearer channels;
- impulse noise protection ≥ minimum impulse noise protection for all bearer channels;
- delay ≤ maximum delay for all bearer channels;
- jitter ≤ maximum jitter for all bearers channels (values of $Lf3_p$, $Lf4_p$, $Ln3_p$, and $Ln4_p$ shall meet the specified jitter requirement, see Table C.7-1). See clause C.K.2.1.1 for valid jitter configuration.

Within those constraints, the receiver shall select the values as to optimize in the priority configured through the CO-MIB channel initialization policy parameter (CIPOLICY, see clause 7.3.2.10 of [ITU-T G.997.1]). The channel initialization policy applies only for the selection of the values exchanged in the PARAMS message during initialization, and does not apply during showtime.

The following channel initialization policies are defined:

- Policy ZERO: if $CIpolicy_n = 0$, then:
  1) Maximize net data rate for the bearer channel #n, per the allocation of the net data rate, in excess of the sum of the minimum net data rates over all bearer channels (see clause 7.10.2).
  2) Minimize excess margin with respect to the maximum noise margin *MAXSNRM* through gain scalings (see clause 8.6.4). Other control parameters may be used to achieve this (e.g., PCB see clause 8.13.3).
- Policy ONE: if $CIpolicy_n = 1$, then:
  1) Maximize INP_act_n for the bearer channel #*n*.

If the CO-MIB sets CIPOLICY (see clause 7.3.2.10 of [ITU-T G.997.1]) to ONE for a bearer channel, it shall have the minimum net data rate (see clause 7.3.2.1.1 of [ITU-T G.997.1]) set equal to the maximum net data rate (see clause 7.3.2.1.3 of [ITU-T G.997.1]) and shall have the *MAXSNRM* set to infinity (see clause 7.3.1.3.3 of [ITU-T G.997.1]).

If only a single bearer channel is configured through the CO-MIB, then the CIPOLICY shall be set to ZERO or ONE for the bearer channel. If multiple bearer channels are configured through the CO-MIB, then the CIPOLICY shall be set to ZERO for each of the bearer channels. The use of channel initialization policy ONE with multiple bearer channels is for further study.

Support of channel initialization policy ZERO is mandatory. Support of channel initialization policy ONE is optional. Additional channel initialization policies are for further study. The $CIpolicy_n$ parameter values other than zero and one, are reserved for use by ITU-T.

Table C.7-2 – Format for PMS-TC PARAMS information

Octet Number [i]	Format PMS-TC Bits [8*i+7 to 8*i+0]	Description
•••		
Octet 10	[rrrr 0DDD] bit 7 to 0	The bits rrrr0DDD give the value of R_P and D_P for latency path #0. The rrrr and DDD bits are coded as defined in Table 7-18. They are always present and set to zero if not used.
	[DDDD 1rrr] bit 7 to 0 (Note)	The bits DDDD and rrr give the value of $D_0 > 64$ and $R_0 > 0$ for latency path #0. The DDDD shall represent the n value as defined in Table 7-18. The rrr shall represent the R_0 as an unsigned 3-bit value and shall be one of the non-zero valid R_0 values divided by 2, minus 1.
•••		
NOTE – This octet format shall only be used to configure optional D_0 values for the downstream latency path #0.		

Add row at the end of Table C.K.2-1 as follows:

Table C.K.2-1 – ATM-TC parameters

Parameter	Definition
•••	
Channel initialization policy *CIpolicy*$_n$	This parameter controls the policy to be applied to bearer channel #*n* in setting the transceiver configuration parameters during initialization (see clause C.7.10.3).

Modify last row and add row at the end of Table C.K.2-2 as follows:

Table C.K.2-2 – Valid configuration for ATM-TC function

Parameter	Capability
•••	
Jitter_max$_n$	$1 \leq jitter\_max_n \leq$ the largest value of $jitter_p$ (see Table C.7-1) for supported valid framing configurations. $Jitter\_max_n = 31$ is a special value indicating no jitter bound is being imposed. In case of downstream $Jitter\_max_n$ coded in G.994.1 CLR message and upstream $Jitter\_max_n$ coded in G.994.1 CL and CLR message, the value "31" is exchanged. $Jitter\_max_n = 0$ is a special value indicating that this bearer is mapped in a latency path where $Lf3_p = Lf4_p = Ln3_p = Ln4_p$.
CIpolicy$_n$	0, 1

Add row at the end of Table C.K.2-3 as follows:

Table C.K.2-3 – Mandatory downstream configuration for ATM-TC function #0

Parameter	Capability
•••	
CIpolicy$_n$	0

Add row at the end of Table C.K.2-4 as follows:

Table C.K.2-4 – Mandatory upstream configuration for ATM-TC function #0

Parameter	Capability
…	
$CIpolicy_n$	0

Add new clause C.K.2.2 as follows:

C.K.2.2 Initialization procedure (supplements clause K.2.10)

The ATM-TC parameter block of Npar(3) octets in CLR and CL (see Table C.K.2-5) and MS (see Table C.K.2-6) messages shall contain one additional octet for the value of *jitter*.

Table C.K.2-5 – Format for an ATM-TC CL and CLR message

	Definition of the parameter block of Npar(3) octets
	A parameter block of 11 octets, containing: – the maximum supported value of *net_max*; – the maximum supported value of *net_min*; – the maximum supported value of *net_reserve*; – the maximum supported value of *delay_max*; – the maximum supported value of *error_max*; – the minimum impulse noise protection *INP_min*; – the support of *IMA_flag;* – the maximum supported value of *Jitter_max*; and – the *CIpolicy* bitmap (see Note in Table K.6). The format of the octets is as described in Table K.6. The *IMA_flag* is a single bit indication, set to 1 if IMA is supported and set to 0 if IMA is disabled or not supported.

Table C.K.2-6 – Format for an ATM-TC MS message

	Definition of the parameter block of Npar(3) octets
	A parameter block of 11 octets containing: – the value of *net_max*; – the value of *net_min*; – the value of *net_reserve*; – the value of *delay_max*; – the value of *error_max*; – the minimum impulse noise protection *INP_min*; – the value of the *IMA_flag;* – the maximum supported value of *Jitter_max*; and – the *CIpolicy* bitmap (see Note in Table K.7). The format of the octets is as described in Table K.15.

Add Appendix VIII as follows:

Appendix VIII

Impact of loop and ATU impedance mismatch on the Hlog accuracy

(This appendix does not form an integral part of this Recommendation)

This appendix provides a discussion regarding the effects on measured accuracy of Hlog when there is a mismatch between a nominal loop termination impedance of 100 Ω and the actual termination impedance (Z_{ATU}) provided by the ATU. This appendix is meant to provide additional technical details regarding clause 8.12.5.1.1 on accuracy requirements for the HLOGps test parameter.

VIII.1 Impact of impedance mismatch on the Hlog error

Figure VIII.1 shows the reference diagram for computing reference received PSD with a spectrum or network analyser.

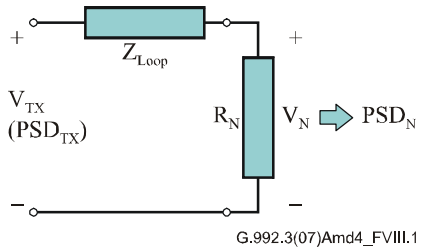

Figure VIII.1 – Measurement of PSD received by network or spectrum analyser

Z_{loop} is the impedance of the loop as seen by the network analyser looking into the test loop. Note that this loop impedance is dependent on the loop topology and may vary with frequency.

R_N is the input impedance of the network analyser and we assume $R_N = 100\ \Omega$. This value is independent of frequency.

The power spectral density of the received signal as seen by the network analyser may be represented as:

$$PSD_N = \frac{\left|V_{Tx}\right|^2}{\Delta f} \cdot \frac{R_N}{\left|Z_{loop} + R_N\right|^2} \qquad \text{(VIII.1)}$$

with Δf representing the subcarrier spacing of 4.3125 kHz.

Figure VIII.2 shows the reference diagram for computing the PSD received by the ATU.

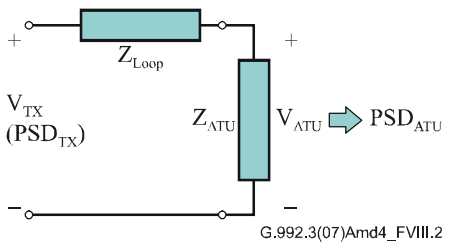

Figure VIII.2 – Measurement of PSD received by ATU

Z_{loop} is the same loop impedance as for the reference case above in Figure VIII.1; this is the impedance of the line seen by the ATU looking into the loop.

Z_{ATU} is the input impedance of the ATU as seen by the test loop.

The power spectral density of the received signal as seen by the ATU may be represented as:

$$PSD_{ATU} = \frac{\left|V_{Tx}\right|^2}{\Delta f} \cdot \frac{\left|Z_{ATU}\right|}{\left|Z_{loop} + Z_{ATU}\right|^2} \qquad \text{(VIII.2)}$$

with Δf representing the subcarrier spacing of 4.3125 kHz.

The difference between equations VIII.1 and VIII.2 is the error in the receive PSD. Assuming that the transmit PSDs are identical for each case, this difference would represent the error in the HLOGps measurement. Hence, the HLOGps error in dB may be represented as follows:

$$Error_{dB} = 10 \cdot \log\left(\frac{PSD_N}{PSD_{ATU}}\right) = 10 \cdot \log\left(\frac{(R_N)}{\left|Z_{ATU}\right|} \cdot \frac{\left|Z_{ATU} + Z_{loop}\right|^2}{\left|R_N + Z_{loop}\right|^2}\right) \qquad \text{(VIII.3)}$$

The above error expression in dB per equation VIII.3 also represents the (contribution of Z_{loop} and Z_{ATU} variation to the) HLOGps accuracy in dB. Figure VIII.3 shows a plot of the HLOGps error in dB vs the ATU input impedance, for different loop impedances that vary from 10 Ω to 200 Ω.

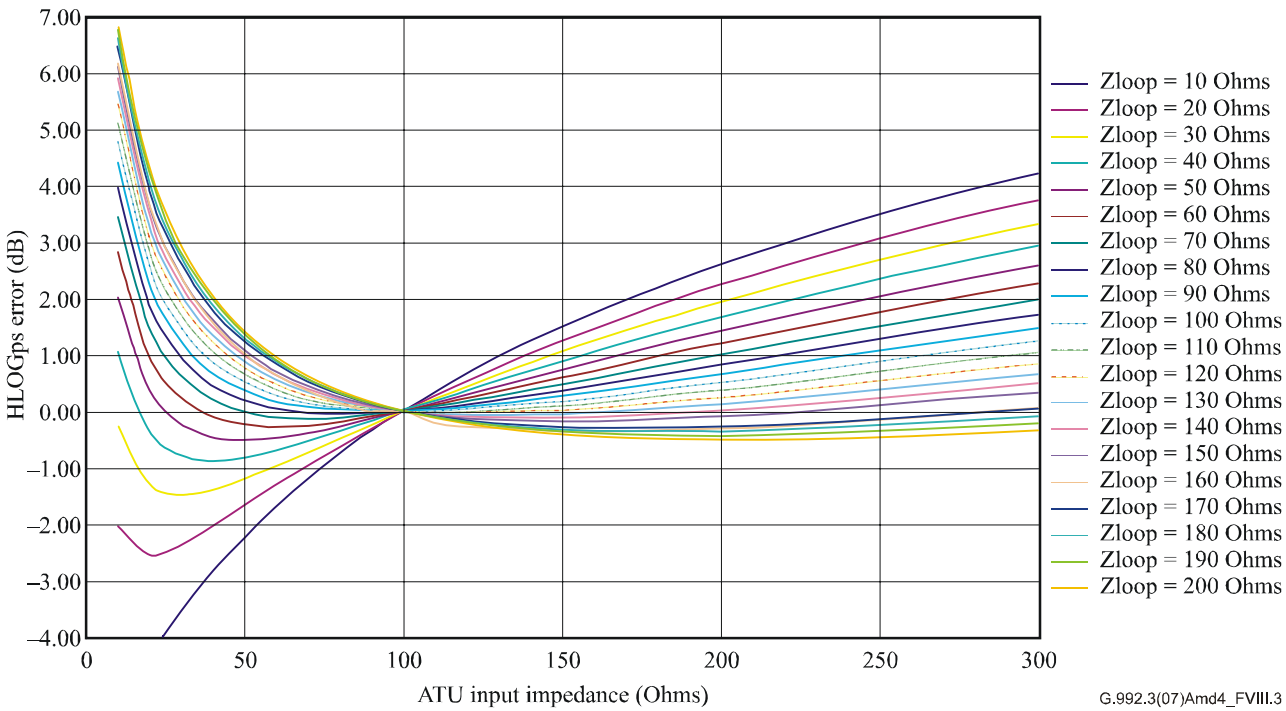

Figure VIII.3 – HLOGps error in dB as function of loop and ATU impedance variations

Regarding the variation of HLOGps error with input impedances, the following is noted:

- This Recommendation does not define any input impedance requirements for ATUs. Similarly, this Recommendation does not define any requirements on return loss. Therefore, ATU implementers are free to design for any input impedance to optimize ATU performance.
- Although it is noted that the transmit PSD is reported relative to 100 Ω, the loop impedance will generally be different from 100 Ω and the resulting transmit PSD will vary accordingly.
- The ATU input impedance varies among those from different manufacturers.
- The ATU input impedance varies with frequency, which is dependent on implementation.
- If the ATU input impedance is equal to the reference impedance of the network analyser, i.e., $Z_{ATU} = R_N$, and everything else is perfect, then the error is zero.
- The curves in Figure VIII.3 do not include any tolerance for components inside the ATU. This tolerance is implementation-dependent.

Note that the actual input impedance of an ATU is complex. The impedance values shown in Figure VIII.3 are the equivalent real Ohmic values.

VIII.2 Setting the accuracy requirement for HLOGps

The HLOGps accuracy requirement is set to ±3 dB for a loop impedance that may vary between 100 and 120 Ω. The ATU impedance tolerance and the ATU component tolerance contribute to the overall ATU tolerance. The actual partitioning of the ±3 dB to each of the tolerance sources is implementation-specific. The following are examples of such partitioning:

- With an uncompensated ATU input impedance of 30 Ω, Figure VIII.3 shows that the highest HLOGps error is ±2 dB, and component tolerance may be up to ±1 dB. Compensating for ATU impedance (relative to 100 Ω) results in lower ATU impedance tolerance and allows higher component tolerance.

- With an ATU input impedance of 100 Ω, Figure VIII.3 shows that there is no HLOGps error, and component tolerance may be up to ±3 dB.

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