Application Report
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ADSL Power Spectrum Density Calculation

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ABSTRACT

This article describes how to measure ADSL transmission power spectrum density (PSD), and how to calculate signal voltage based on PSD. These calculations can help in designing over voltage protection circuits for ADSL and in debugging ADSL analog circuitry.

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1 Transmission PSD Mask in G.dmt

G.dmt defines both ATU-C and ATU-R transmission maximum PSD masks as shown in Figure 1 and Figure 2. The purpose of the limitation of the PSD mask is to reduce cross-talk noise and to limit power consumption.

Figure 1 shows the ATU-C downstream transmission spectral mask.

The band for DSL is from 25 kHz to 1 104 kHz. The overlapped spectrum downstream band (for the non-overlapped spectrum) should be from 138 kHz to 1104 kHz.

The PSD mask in this band is –36.5dBm/Hz.

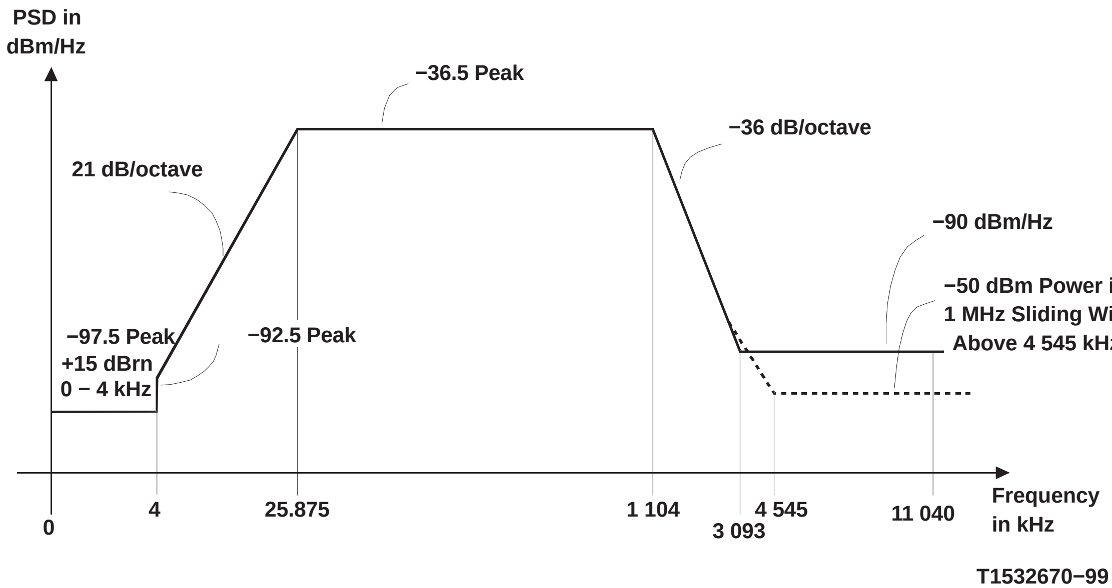

Figure 1. ATU-C Downstream Transmission Spectral Mask [Ref G.dmt]

Figure 2 shows the ATU-R upstream transmission spectral mask. The band from 25 kHz to 138 kHz is for DSL upstream. The limitation in this band is –34.5dBm/Hz.

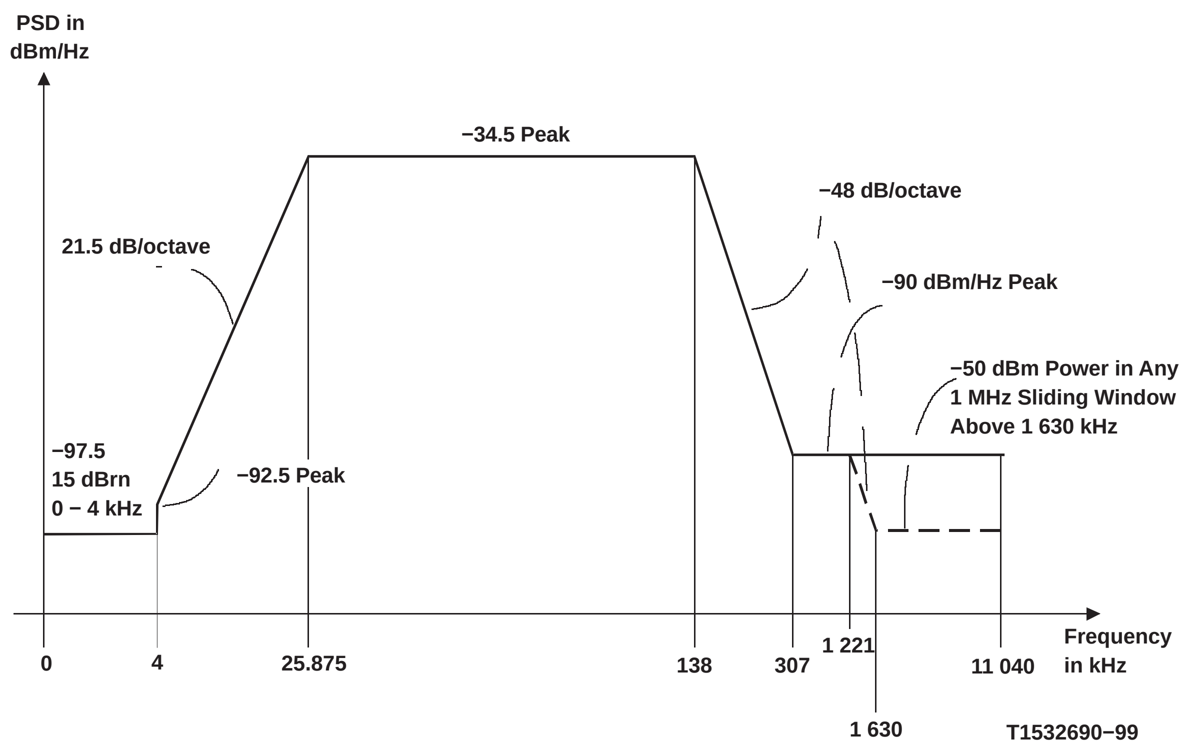

Figure 2. ATU-R Transmission spectral mask [Ref G.dmt]

2 DSL Transmission PSD Measurement

Both the central office (CO) and the customer premise equipment (CPE) should guarantee that its transmission PSD is well below the scope of the PSD mask in G.dmt. The correct way to measure transmission of the PSD mask is to terminate a CO transceiver or a CPE transceiver with a 100 Ohm resistor. Then you would use a high resolution spectral analyzer, and have the device under test transmit a wideband signal, such as the REVERB signal or the MEDLEY signal.

It is not a good idea to terminate with an IDLE status CPE or CO method because not all DSL products have a perfect 100 Ω load.

3 CO PSD Calculation

Power spectrum density is described in units of dBm/Hz. Sometimes it is useful to know the approximate signal voltage based on the PSD. The following section describes how to calculate signal voltage based on the PSD.

Besides the maximum downstream PSD mask, G.dmt also indicates that the **average nominal** PSD within the downstream pass band shall be no greater than −40 dBm/Hz. The average nominal PSD level is the PSD level that occurs during training and show time if no power adjustment is applied.

NOTE: Power adjustment includes power cutback and bit and gain table adjustment.

In fact, the maximum PSD mask comes from the nominal PSD plus possible pass band ripple, which G.dmt limits to be no greater than +3.5 dB. The final downstream maximum PSD mask becomes (−40 + 3.5) dBm/Hz = −36.5dBm/Hz, as shown in Figure 1.

The nominal downstream power in one tone:

= nominal PSD * 4.3125 kHz

=−40 dBm/Hz +10log4312.5

=−3.6527 dBm

=0.43125 milliwatt

If this single tone is regarded as a pure sine wave, the rough voltage can be calculated:

Vrms = sqrt (Power * Termination Resistor)

= sqrt (0.43125 milliwatt * 100ohm)

= 0.21 V

Vpeak-peak on TIP/RING = Vrms * 1.4142=0.3 V

If all tones are assumed to be used and they are all at nominal PSD level, a rough nominal aggregate transmission power can be calculated:

The nominal downstream aggregate transmission power:

= nominal PSD * (1104 kHz – 25.875 kHz)

= −40 dBm/Hz + 10log1078125

= 20.33 dBm

= 107.895 milliwatt

The whole DSL downstream rough average voltage can also be calculated:

Vrms = sqrt (Power * Termination Resistor)

= sqrt(107.895 milliwatt * 100 ohm)

= 3.285 V

This is not a pure sine wave any more. A DMT signal is like a random white noise signal, because each tone changes its amplitude and phase simultaneously. Sometimes, most of tones will get to their highest amplitude together and create a very high peak. If this peak is clipped by line driver, it will cause some errors. Experiments and statistics show it is usually a 5.3 times Voltage/Voltage Peak Average Rate (PAR) that can keep 10^{-7} bit error rate (BER).

5.3*3.285 V = 17.41 V of peak voltage at Tip/Ring or 34.82 V of peak to peak

NOTE: This computation is based on ADSL over POTS implemented with overlapped spectrum.

4 CPE PSD Calculation

Similar to the CO side, G.dmt also defines that the **average nominal** PSD within the upstream pass band shall be no greater than −38 dBm/Hz.

Considering the pass band ripple, which G.dmt limits to no greater than +3.5 dB, the final upstream maximum PSD mask becomes −38 dBm/Hz + 3.5dB = −34.5 dBm/Hz as shown in Figure 2. All of the power-relevant calculations are similar with CO:

The nominal upstream power in one tone:

= nominal PSD * 4.3125 kHz

= −38 dBm/Hz +10log4312.5

= −1.6527 dBm

= 0.6835 milliwatt

If this single tone is regarded as a pure sine wave, the rough voltage can be calculated:

Vrms = sqrt (Power * Termination Resistor)

= sqrt (0.6835 milliwatt * 100 ohm)

= 0.26 V

Vpeak-peak on TIP/RING =Vrms * 1.4142=0.37 V

If all tones are assumed to be used and they are all at nominal PSD level, the rough nominal aggregate transmission power can be calculated:

The nominal upstream aggregate transmission power:

= nominal PSD * (138 kHz – 25.875 kHz)

= −38 dBm/Hz + 10log112125

= 12.5 dBm

= 17.783 milliwatts

Whole DSL upstream rough average voltage can also be calculated:

Vrms = sqrt (Power * Termination Resistor)

= sqrt (17.783 milliwatt * 100 ohm)

= 1.3335 V

This is not a pure sine wave any more, and it has a very big Peak Average Ratio (PAR). Let’s assume 5.3 times Voltage/Voltage PAR.

5.3*1.3335 V = 7.07 V of peak voltage at Tip/Ring or 14.14 V of peak to peak

5 Conclusion

The calculations above provide the ability to choose an appropriate over-voltage protection circuit for DSL without clipping a normal DSL signal. This information can also assist in capturing an abnormal ADSL signal when bringing up a new board.

6 References

1. *“DRAFT NEW RECOMMENDATION G.992.1”,* July 1999, ITU Study Group.

Appendix A

A.1 Key Words

DMT: discrete multi-tone modulation

G.DMT: ITU ADSL standard , also named G.992.1

PSD: power spectrum density

ATU-C : ADSL transceiver unit at central office end, also named central office(CO)

ATU-R : ADSL transceiver unit at remote terminal end, also named customer premise equipment (CPE)

showtime: the state of either ATU-C or ATU-R − reached after all initialization and training is completed − in which user data is transmitted.

PCB: power cut back

B&G: bit and gain table

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