

WHITE PAPER

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greater reach

higher data rates

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REACH-EXTENDED ADSL₂ **Expanding the Addressable Market for DSL Services**

Revision 3



A W A R E

Carriers worldwide continue to deploy ADSL at a rapid pace; there are currently over 60 million ADSL subscribers worldwide. But while high-speed Internet access services are in great demand, a significant proportion of potential subscribers live outside the range of current ADSL technology, particularly in North America but also in Europe and Asia.

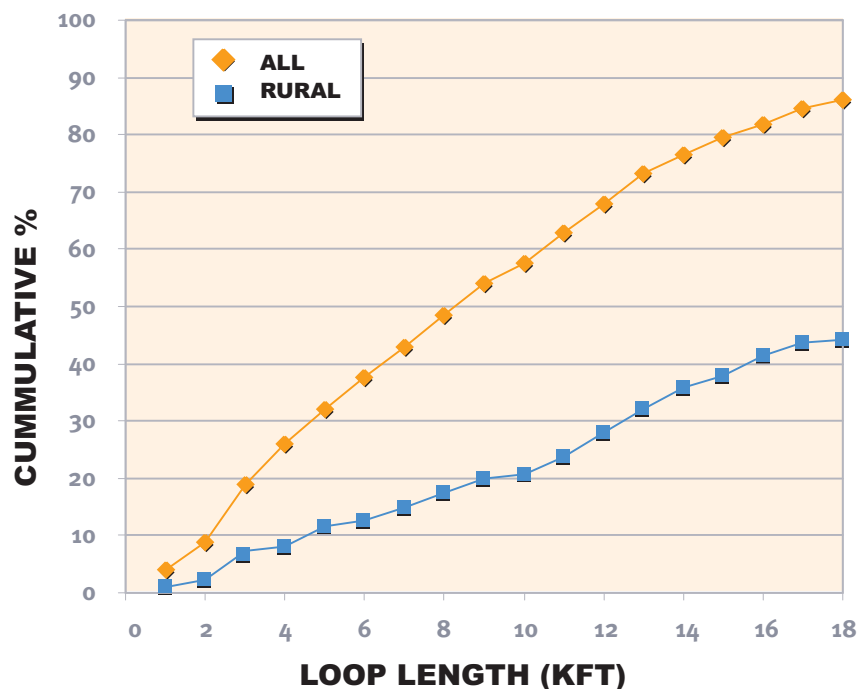
Figure 1 shows that well over half of rural customers in the U.S. reside outside the range of operation of ADSL. In these cases, carriers are forced to deny service to customers, so the ability to extend the range of ADSL in order to reach these customers is very valuable to them in expanding their addressable market. In response to this demand, a new member of the

ADSL2 standards family specifies a means to extend the reach of ADSL technology as much as 3,000 feet, effectively expanding the coverage area of ADSL by up to 40%. The new standard is called Reach-Extended ADSL2, or ADSL2 Annex L.

STANDARDS APPROVAL

The Reach-Extended (RE) mode of operation in the ADSL2 standard was officially ratified at the annual ITU meeting in Geneva, held in October 2003. "Annex L: Specific Requirements for a Range Extended ADSL System Operating in the Frequency Band above POTS". provides loop reach improvements from 500 feet to 3,000 feet.

FIGURE 1: U.S. LOOP PLANT DATA



OVERVIEW OF REACH EXTENDED ADSL2 ANNEX L (RE-ADSL2)

RE-ADSL2 Annex L [1] contains specifications for reach-extended operation of ADSL2 systems operating over POTS. Annex L contains one mandatory downstream power spectral density (PSD) mask, one optional downstream PSD mask, and two mandatory upstream PSD masks. (see Figures 3 through 6)

Analysis of these PSDs shows that increased loop reach is achieved by transmitting at higher PSD levels while using less frequency bandwidth than ADSL2 systems operating over POTS. For example, Annex A ADSL2 (non-reach extended) has a peak in-band upstream PSD of -34.5 dBm/Hz upstream and a

peak in-band downstream PSD of -36.5 dBm/Hz. Figures 3 and 4 show that the in-band downstream PSD for RE operation is up to 3 dB higher (i.e. -33.5 dBm/Hz) for certain frequency regions. Figure 5 shows that the in-band RE upstream PSD mask #1 is 1.6 dB higher (i.e. -32.9 dBm/Hz) than Annex A ADSL, while Figure 6 shows that the in-band reach-extended upstream PSD Mask #2 is 5.1 dB higher (i.e. -29.4 dBm/Hz) than Annex A ADSL.

On the other hand, all the reach-extended PSD masks transmit over a smaller frequency bandwidth than Annex A ADSL. In particular, both of the reach-extended downstream PSD masks stop at 552 kHz whereas the Annex A downstream PSD uses approximately 1104 kHz

bandwidth (twice the bandwidth). Likewise, the upstream PSD masks #1 and #2 use approximately only 78 kHz and 35 kHz bandwidths respectively, whereas the Annex A upstream PSD uses approximately 112 kHz bandwidth.

This tradeoff between bandwidth and PSD levels is an important aspect of the RE-ADSL2 system in that it allows reach-extended systems to be deployed in the same environment as legacy ADSL systems without causing them serious harm. The reach-extended PSD masks were carefully chosen to be spectrally compatible according to ANSI Standard T1.417, the standard that specifies spectrum compatibility requirements in North America.

FIGURE 2: ADSL ANNEXES

ANNEX	ENVIRONMENT	USE OF TONES					APPLICABLE TO:		
		1-5	6-31	32-64	65-255	256-512	ADSL G.992.1	ADSL2 G.992.3	ADSL2+ G.992.5
A	POTS	POTS	UP	DOWN	DOWN	DOWN*	YES	YES	YES
B	ISDN	ISDN	ISDN	UP	DOWN	DOWN*	YES	YES	YES
C	TCM-ISDN	POTS	UP	DOWN	DOWN	N/A	YES	YES	YES
I (ADSL)	TCM-ISDN	POTS	UP	DOWN	DOWN	DOWN	YES	NO	NO
I (ADSL2)	POTS	UP	UP	DOWN	DOWN	DOWN*	NO	YES	YES
J	ISDN	UP	UP	UP	DOWN	DOWN*	NO	YES	YES
L (RE-ADSL2)	POTS	POTS	UP **	DOWN **	DOWN **	N/A	NO	YES	NO
M (ADSL2+)	POTS	UP	UP	UP	DOWN	DOWN*	NO	YES	YES

Use of tones applies to the non-overlapped PSD masks only
 * ADSL2+ only
 ** Not all tones are used

FIGURE 3: MANDATORY NON-OVERLAPPED SPECTRUM DOWNSTREAM PSD MASK

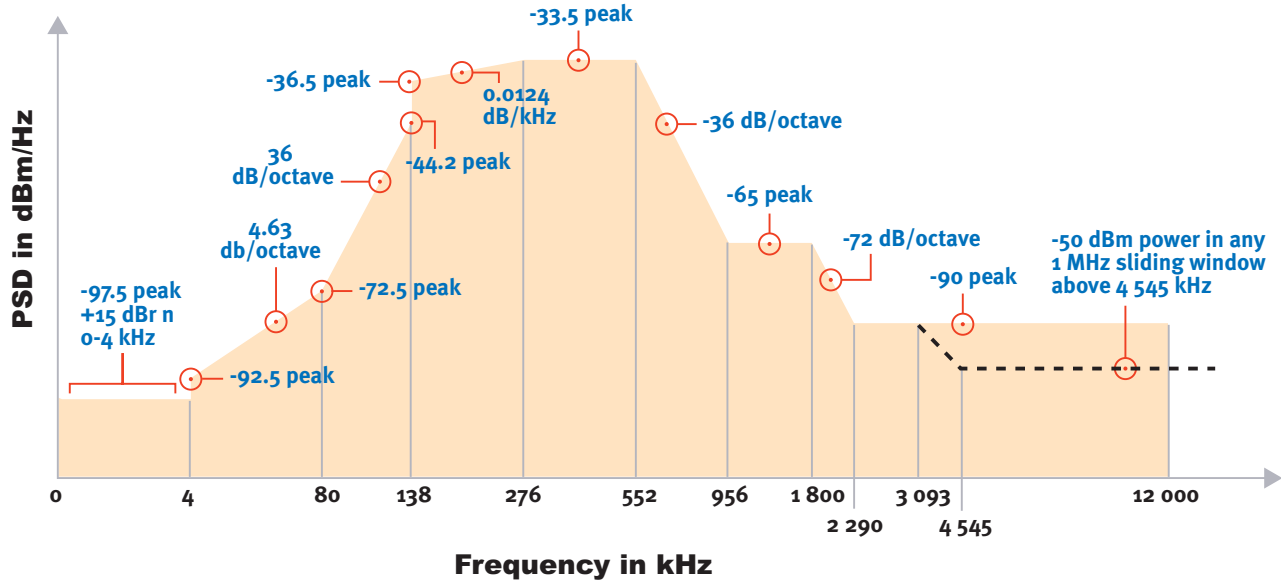


FIGURE 4: OPTIONAL OVERLAPPED SPECTRUM DOWNSTREAM PSD MASK

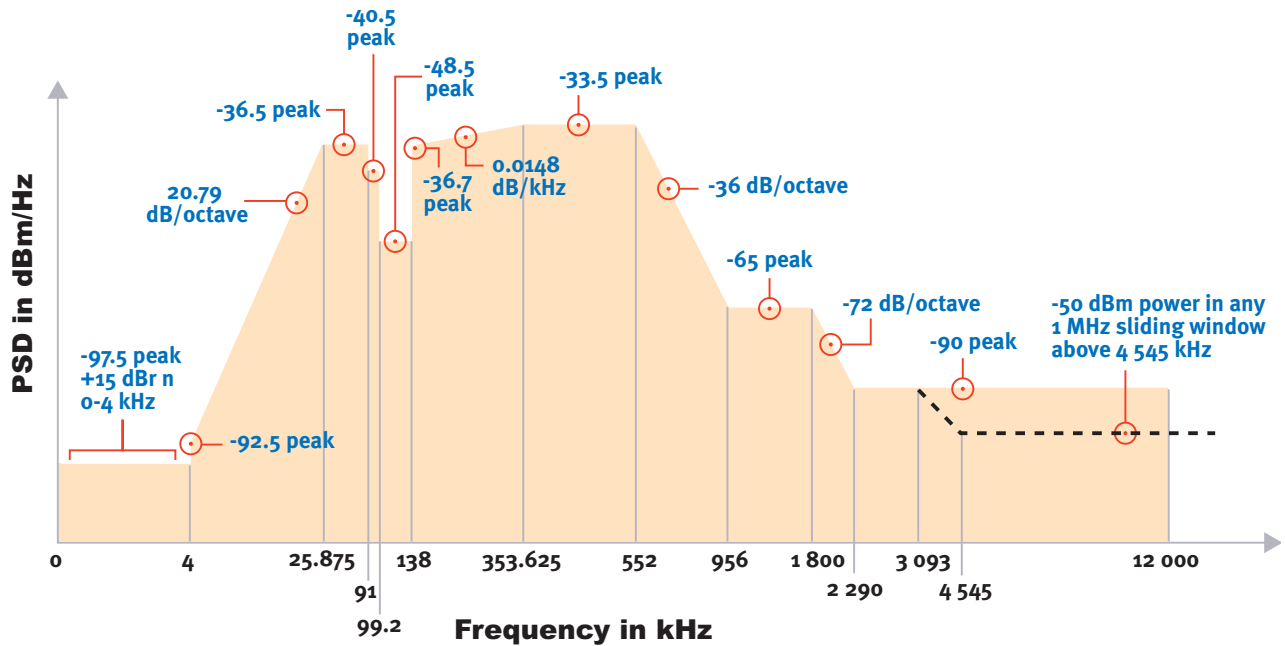


FIGURE 5: UPSTREAM PSD MASK #1

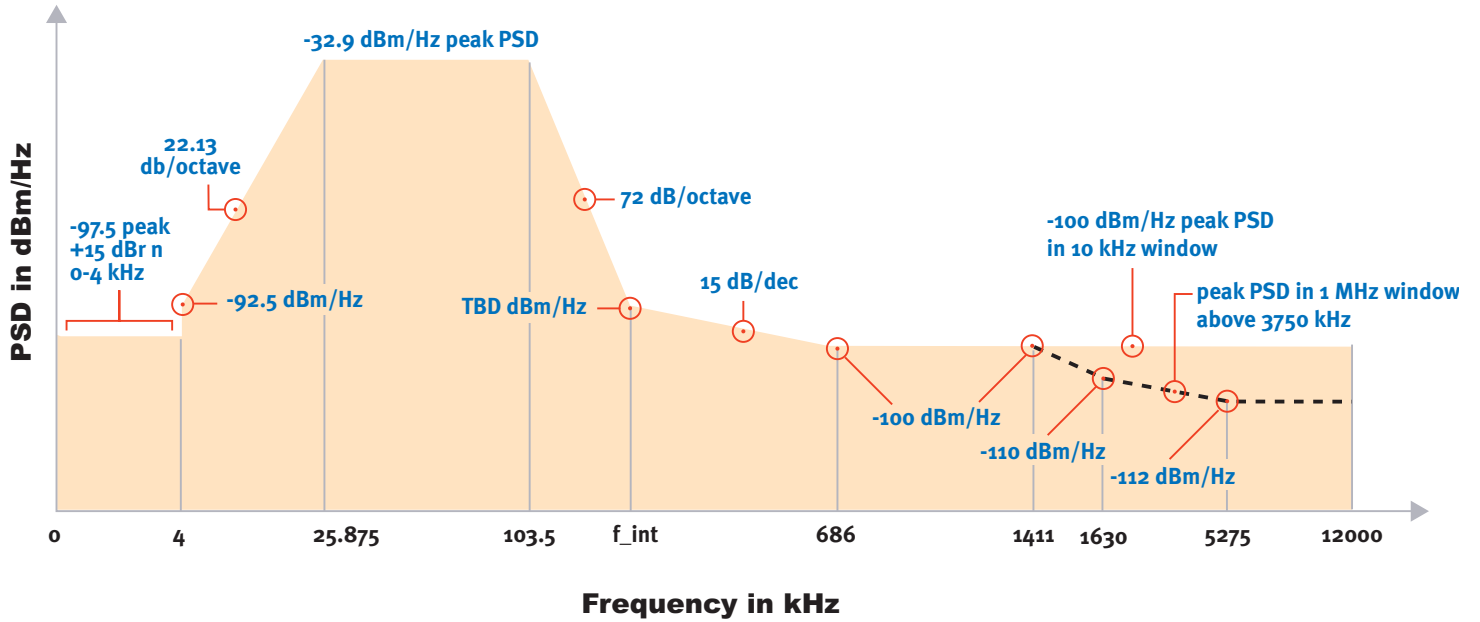
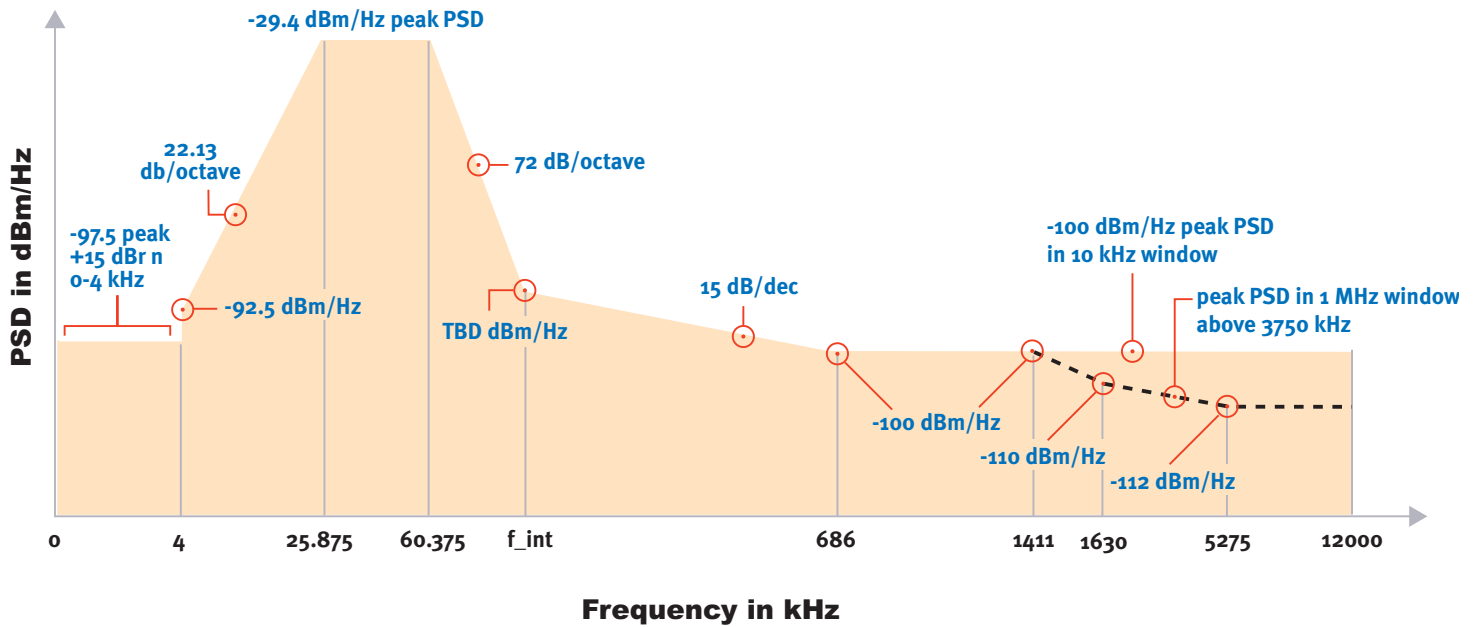


FIGURE 6: UPSTREAM PSD MASK #2

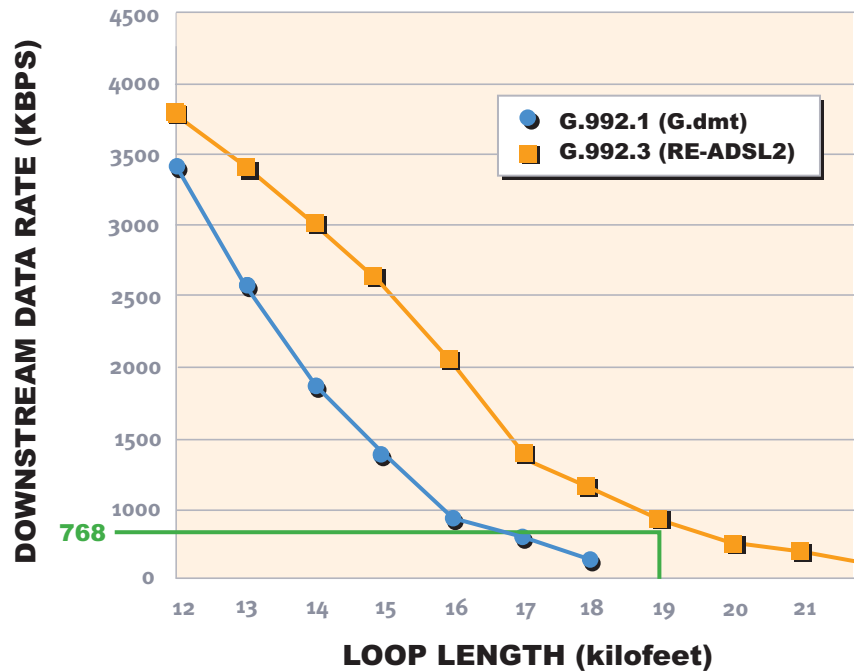


PERFORMANCE OF THE REACH-EXTENDED ADSL2 SYSTEM

Reach-Extended ADSL2 systems provide increased performance on long lines under various crosstalk conditions. The increase in transmit PSD levels result in increased data rates, which are achieved even though the overall transmit bandwidth is less than Annex A ADSL systems. This is primarily because the higher frequency spectrum is not usable on long lines due to the large channel attenuation. As a result, RE-ADSL2 systems provide an increase in data rate on shorter lines (where the high frequency spectrum is good) as compared to Annex A systems, even though they use less overall bandwidth.

The Reach-Extended ADSL2 system was evaluated under a large number of crosstalk conditions and loop topologies [2,3,4]. Figure 7 compares the downstream data rate performance of conventional ADSL systems based on G.992.1 (G.dmt) and RE-ADSL2 systems based on G.992.3.

FIGURE 7: G.DMT ADSL VERSUS RE-ADSL2 DOWNSTREAM PERFORMANCE

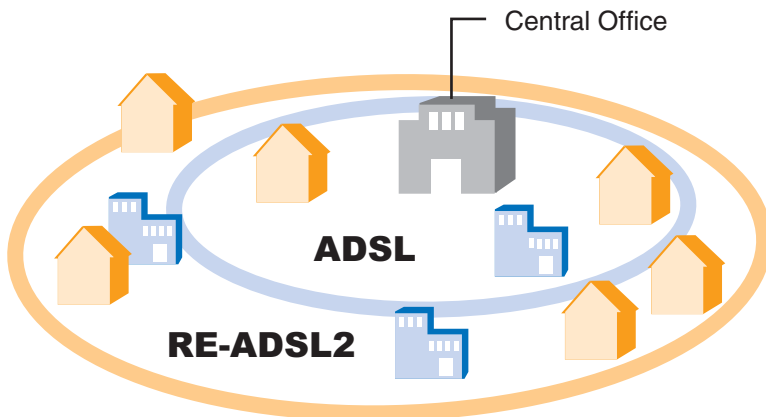


The crosstalk environment for this test case is white noise injected at the RT. Under these test conditions RE-ADSL2 extends a 768 Kbps downstream service approximately 3,000 feet to 19,000 feet. As a result, the coverage area for this service increases about 37% (see Figure 8).

SELECTING THE PSD FOR MAXIMUM LOOP REACH

The RE PSD masks were specifically designed to provide improved loop reach under a large variance of deployment guidelines, crosstalk conditions, and loop topologies. The resulting data shows that different combinations of the upstream and downstream RE-ADSL2 PSD masks will provide the best loop reach performance, depending on these conditions. It is expected that selection of the best combination of PSDs by the operator will be possible, based on knowledge of the loop conditions in the network. Additionally, the standard will provide a mode of operation where the ADSL transceivers are allowed to autonomously select the best combination of PSD masks during initialization.

FIGURE 8: RE-ADSL2 EXTENDS COVERAGE AREA OF 768 KBPS SERVICE APPROXIMATELY 37%



Another important aspect of the RE-ADSL2 system is that it is designed so that the RE mode of operation can be easily implemented on a system (CO or CPE modem) that supports Annex A ADSL2 operation. This is accomplished by utilizing RE PSD masks that are achievable by simply turning off carriers and/or shaping the PSD on each carrier of the multicarrier modulation system. It is important that RE operation be provided on an Annex A ADSL2 modem because service providers are expected to enable the RE mode of operation only on the long lines which constitute a small percentage of the entire phone network. As such, it does not make sense to have dedicated line cards for RE mode of operation. As noted above, it is not desirable to operate in RE mode when operating on regular length telephone lines because the data rates will be lower than Annex A ADSL2 systems.

CONCLUSION

RE-ADSL2 introduces a new era of standard-compliant products to address the rate/reach challenge. It represents one of many areas where the ITU has worked in direct response to carrier requirements in order to enable DSL product vendors to deliver valuable solutions to the marketplace. Reach-Extended ADSL2 promises to be yet another example of DSL standards driving interoperability, performance, and healthy competition.

REFERENCES:

- [1] ITU-T Document TD-READSL-WP1, "Draft baseline text for Reach Extended ADSL over POTS", Geneva, January 20-31 2003.
- [2] ITU-T Document, OJ-212, "Range Extended ADSL: Proposed Evaluation Conditions" Osaka, Japan - 21-25 October, 2002
- [3] ITU-T Document D587, "Performance Numbers for Range Extended ADSL" Geneva, January 20-31 2003.
- [4] ITU-T Document D588, "More results for Range Extended ADSL" Geneva, January 20-31 2003.
- [5] ITU-T Document TD59, "Amendment 1 to Annex J and new Annex L and M to Recommendation G.992.3" Geneva, October 21-31, 2003.

ABOUT AWARE

Aware, Inc. is a worldwide leader in the development and marketing of semiconductor intellectual property (IP) for broadband communications. Our focus is DSL technology which enables high-speed data, voice and video over telephone lines. We deliver complete IP platforms which our customers can easily integrate into system-on-chip solutions. Our technology offerings consist of complete RTL, software, and reference designs. Aware is headquartered in Bedford, Massachusetts, and has approximately 125 employees. Aware is a publicly traded company on the NASDAQ Stock Exchange (symbol: AWRE).

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