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CONTRIBUTION

TITLE: **Higher-Rate Level 2 DSM Power-Saving Examples**

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ABSTRACT

This contribution responds to requests for additional examples to illustrate the gains in contributions [1], and [2] from the September 2007 NIPP-NAI meeting. In particular, a method for computing and passing a cut-off frequency for band preference is used and applied to more general channels than a simple near/far (short/long) situation. Further, the gains for better level-1 and level-2 [2] use of margins is described for a more general set of line conditions. This contribution is for information only.

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Higher-Rate Level 2 DSM Power-Saving Examples (160)

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ABSTRACT

This contribution responds to requests for additional examples to illustrate the gains in contributions [1], and [2] from the September 2007 NIPP-NAI meeting. In particular, a method for computing and passing a cut-off frequency for band preference is used and applied to more general channels than a simple near/far (short/long) situation. Further, the gains for better level-1 and level-2 [2] use of margins is described for a more general set of line conditions. This contribution is for information only

1. Introduction

Distributed Band Preference (DBP) [1] achieves near-optimal Level 2 DSM performance with very little computational/control burden. An SMC with DBP capability classifies lines as either weak or strong lines depending on the relative difficulty or ease that they may achieve the desired customer data rate. Strong users execute an alternative polite loading algorithm, while weak users execute the usual "greedy" loading algorithm. A cut-off frequency can aid the strong algorithm. Tones below the cut-off become donor tones to tones above the cut-off. This contribution provides additional detailed examples of weak/strong algorithm use, and compares with other Level 1 spectrum management methods such as USPBO and IWF. Also, methods for computing and passing the cut-off frequency are discussed, which provide alternative methods to determine the cut-off frequency than the distributed, local solution described in [1].

Single-bit control (weak/strong) is the main advantage of distributed band preference. That is, there is no central swapping, leaving the essential bit-swapping methods to react to the dynamic DSL binder environment. A cut-off frequency can also be useful and may be recommended elsewhere **Error! Reference source not found.**. Otherwise, DSL modem autonomous operation is retained. The SMC can compute and supply (as a new Level 2 DSM control parameter) the cut-off frequency to any strong user, and this cut-off will help the modem to achieve additional gain. The cut-off frequency can be introduced to attain significant reduction in power consumption, thus satisfying a recent goal of the second DSM Report, and more generally recent DSL standardization. Section 2 also shows the increasing rate/reach effect of using true margins for the same situations as DBP.

2. Examples of weak/strong algorithms

This section provides additional examples of weak/strong algorithms to those in [1]. The strong algorithm initially runs a water-filling algorithm like the weak algorithm. Subsequently, the strong algorithm moves bits from the below-cut-off tones to the above-cut-off tones to reduce crosstalk into the weak lines assuming that the common tones to both lines are typically at lower frequencies. Since long lines can load bits only on lower-frequency tones, this bit-moving process of short lines will be greatly beneficial to long lines through reduced crosstalk. However, this bit-moving process requires the definition of cut-off frequency where good tones and bad tones are divided. One local solution is to divide the frequency region into bands randomly and compare the average SNR of each band to determine the good and bad tones. During the process, the water-level of each band is maintained flat. Another solution is to allow the SMC to send the cut-off frequencies infrequently (that is through hand-shake to be used upon initialization or re-initialization). Since the SMC has enough information about the lines, it can compute the cut-off frequencies and distribute them to its subtended (controlled) DSL modems. Any solutions from other spectrum balancing methods can be good candidates for these cut-off frequencies because the results from spectrum balancing methods are usually well-approximated by several flat bands. For examples of such methods, see the DSM Report issue 1 [3].

2.1 Data rate region for upstream 10 users

Figure 1 shows the line lengths for 10 upstream DSLs. This example will use DSM Level 2 control in the upstream. The Level 2 SMC has all information about these lines including channel gains, crosstalk insertion loss transfers (Xlog), measured noises or SNRs, and rate targets. With this information, the SMC will determine those lines upon which to request the use of the strong algorithm by setting a Level 2 DSM control bit to 1, and which lines will use the weak algorithm (default or setting the same Level 2 DSM control bit set to 0). In this example, the SMC selects lines 1 to 5 for use of the strong algorithm, and lines 6 to 10 for the weak algorithm. Since it is hard to visualize a 10-dimensional rate region, Figure 2 plots a 2-dimensional rate region of R_1 versus $\sum_{i=6}^{10} R_i$, where R_i is the data-rate of line i , by fixing other users rates to [10 8 6 5] Mbps respectively (lines 2 to 5). The DSLs running the weak algorithm will maximize their rates under the VDSL upstream power constraint of 14.5 dBm at 6 dB of margin, and line 1 sweeps its data rate from 0 to 36 Mbps to see its effect on the long lines' rate-sum. As line 1 increases its data rate, the other strong lines also change their power and bit allocations to satisfy their fixed rate-targets. Therefore, the weak lines see increased interference as line 1 increases its data rate. However, as seen in Figure 2, line 1 loads in a polite way to minimize the interference to weak lines. As the rate-target increases, line 1's power inevitably affects other lines, and consequently $\sum_{i=6}^{10} R_i$ decreases as in Figure 2.

For the virtual noise simulations, the worst-case interference is first computed by assuming that all other users transmit at the maximum PSD level over all tones. So, in this example, the maximum virtual noise of each user is obtained by summing up 9 other users' signals as follows:

$$VN_i^{MAX}(n) = \sum_{j=1, j\neq i}^{10} H_{i,j}(n) P_j^{MASK}(n) \ ,$$

where $VN_i^{MAX}(n)$ is the virtual noise of user i at tone n, $H_{i,j}(n)$ is the crosstalk channel gain from user j to user i, and $P_j^{MASK}(n)$ is the maximum PSD level at tone n for user j. The other choice for the virtual noise is to set as the interference from the strongest crosstalker as follows:

$$VN_i(n) = \max_{j \neq i} H_{i,j}(n) P_j^{MASK}(n) \, .$$

For both choices of virtual noise, as seen in Figure 2, achievable rate regions are significantly reduced by introducing virtual noise because all users use unnecessarily high power and strongly interfere with other users.

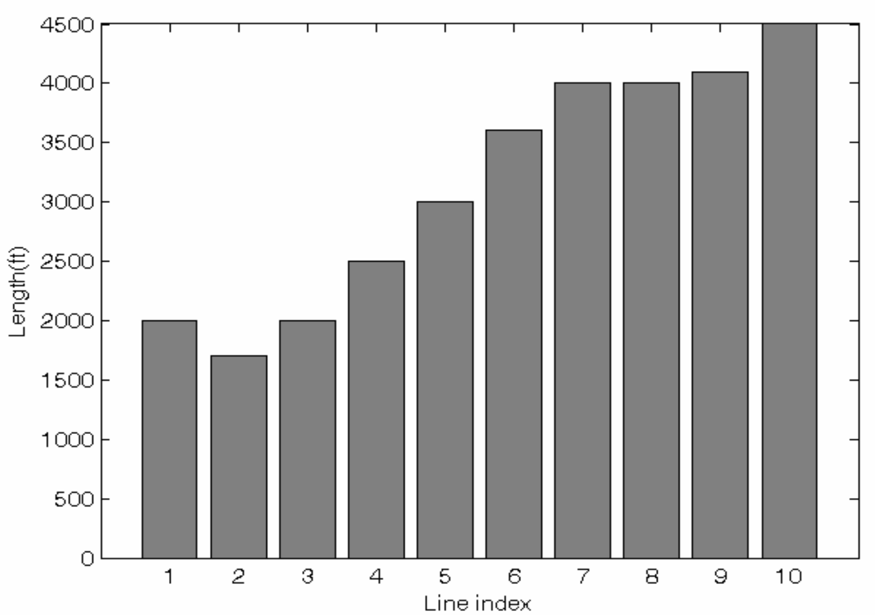

Figure 1 – DSL length distribution for Level 2 DSM Example.

Parameter	Value
Tone Width	4.3125 kHz
Number of Tones	4096
Maximum Upstream Power	14.5 dBmW
Coding Gain	3 dB
Target Margin	6 dB
Gap	9.8 dB
Band-plan	VDSL 2, 17MHz
Bit-cap	15

Table 2.1 – VDSL system parameters.

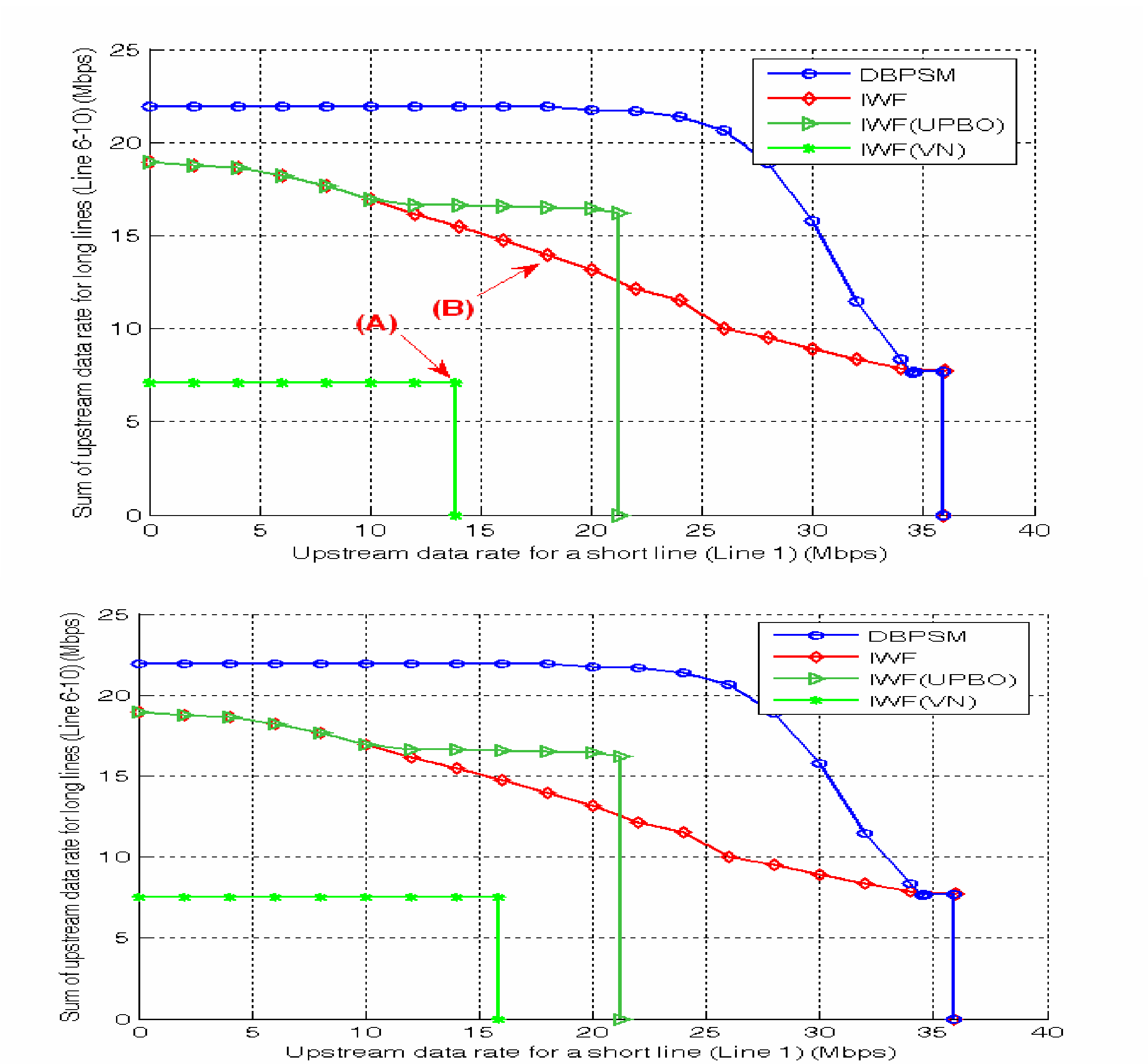

Figure 2(a),(b) – Rate regions for DBPSM, IWF, IWF(UPBO), IWF(VN)

When true margins (noise margins from [2]) are used, a further rate-region enhancement can be obtained. True margins can be translated into equivalent SINR margins so no change to existing DSL modem practice is necessary as already standardized. The SMC can internally effect these translations and thus can instruct different lines to have different margins, rather than to have a practice of a uniform margin (say 6 dB target margin and 16 dB maximum margin) on all lines. Figures 3 and 4, respectively, show the rate region improvements for IWF and DBP by using a 6 dB true margin.

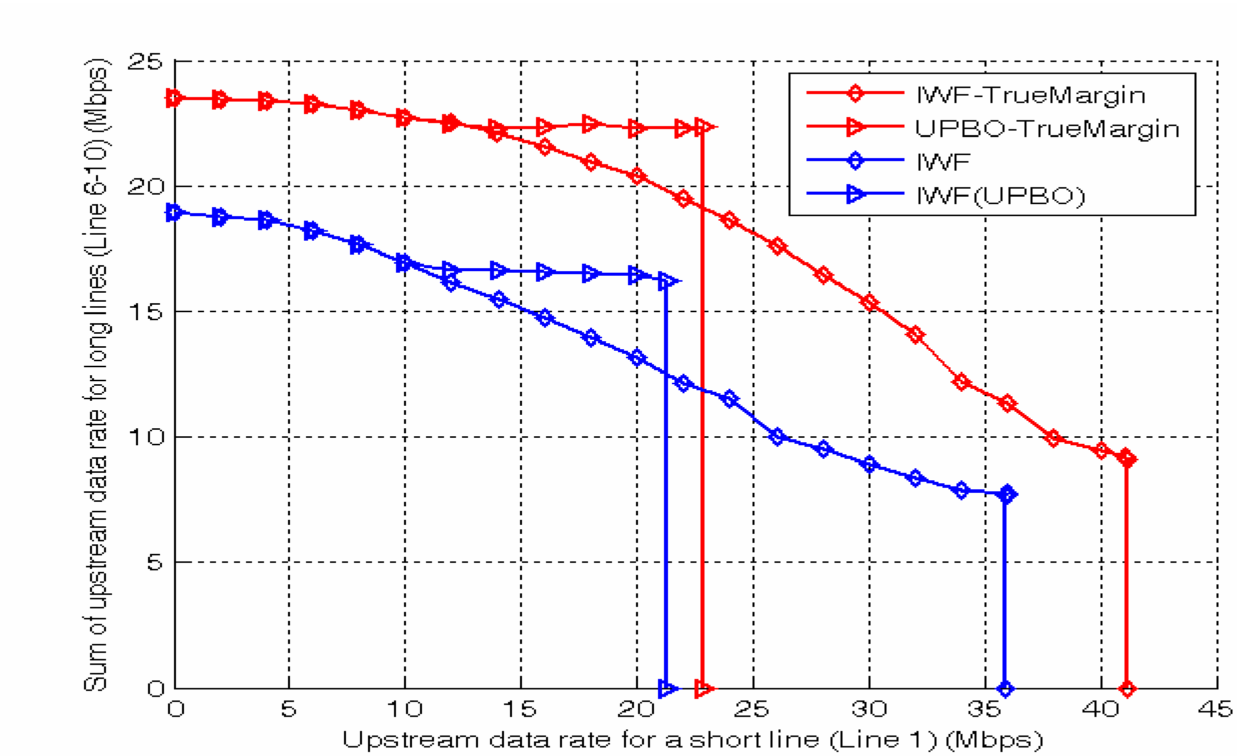

Figure 3– Rate regions enlargement by using 6 dB true margin for IWF (10 users)

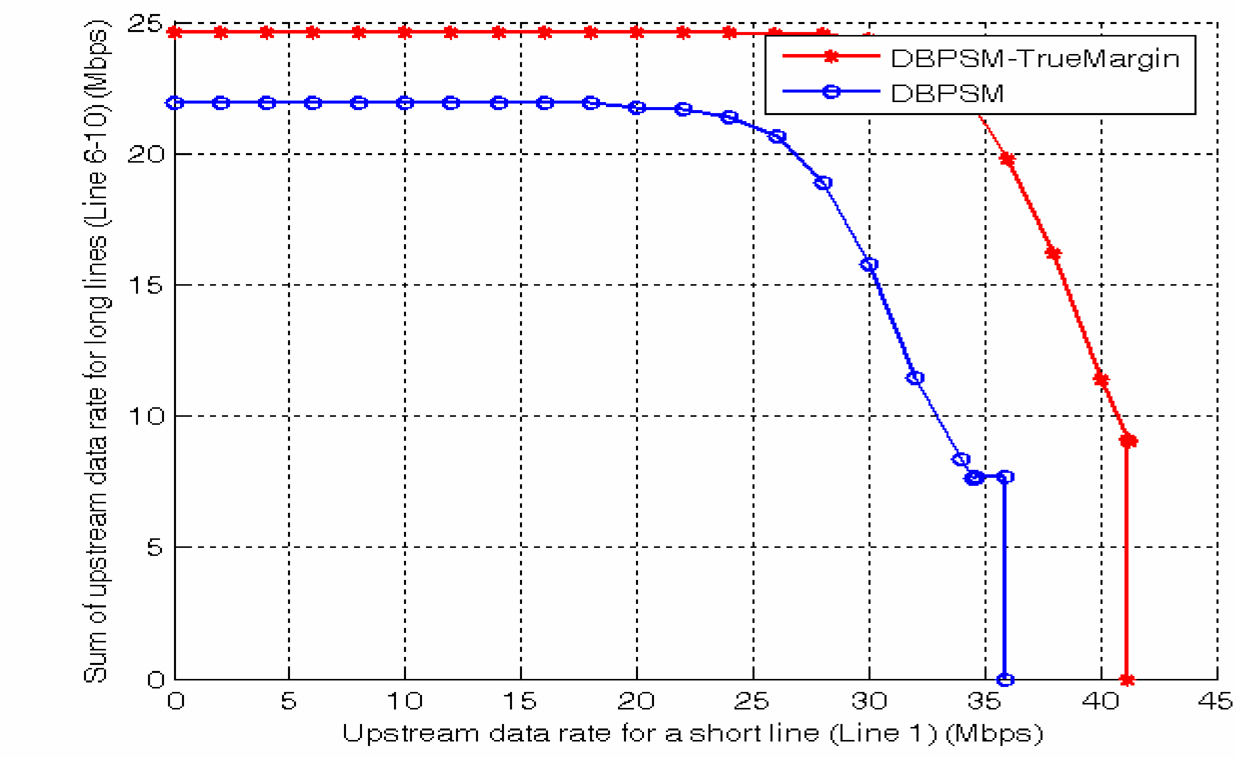

Figure 4– Rate regions enlargement by using 6 dB true margin for DBPSM (10 users)

2.2 Power reduction examples

The previous section shows the enlargement of achievable regions by using Level 2 DSM. Another main benefit of Level 2 DSM is power reduction. The larger rate region means that inner points can be achieved by using less power, and therefore, Level 2 DSM can save power compared to other methods. Figure 5(a) shows the power required per line for achieving point (A) of Figure 2 assuming that the virtual noise is set as the worst-case interference. Figure 5(b) also shows the power to achieve the same point (A) of Figure 2 assuming that the virtual noise is set as the interference from the strongest crosstalker. In this simulation, the probability of being on-state is defined as the probability of being active. Then, there can be 1024 possible line configurations, and the probability of each configuration is computed assuming the independence of activity. For example, the probability of having L(i)= [1 1 0 1 1 1 1 1 0 0] (user 3,9,10 are off) is

$$p(i) = p^7(1-p)^3,$$

where p is the probability of being active. By running simulations for all possible configurations and multiplying the required power with these probabilities, average power of active lines to achieve the rate point (A) can be obtained as follows.

$$P_{avg} = \sum_{i=1}^{1024} p(i)Power(i),$$

where Power(i) refers to the required power for *i*th line configuration.

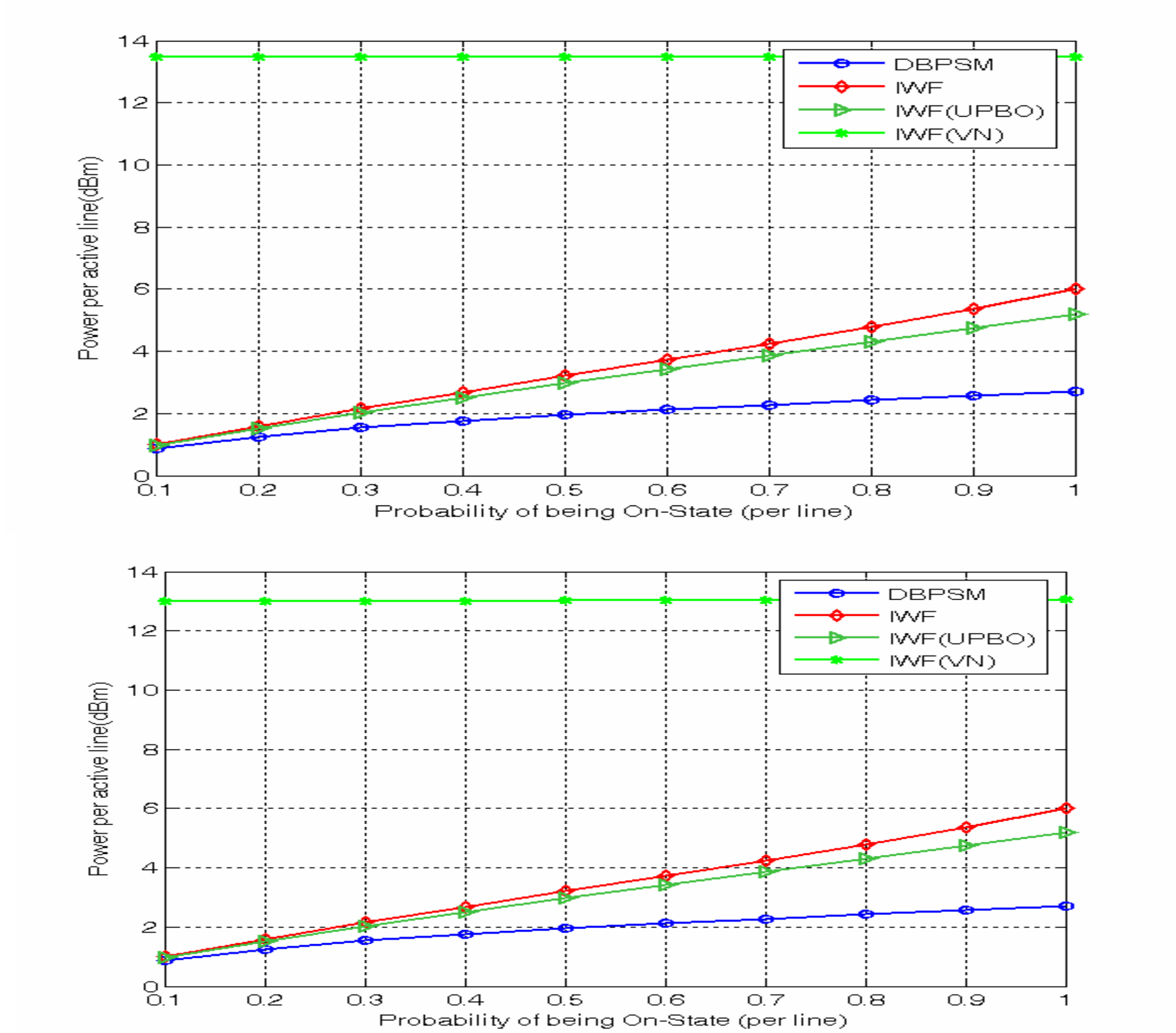

Figure 5(a),(b) – Power reduction with Level 2 for point (A) of Figure 2

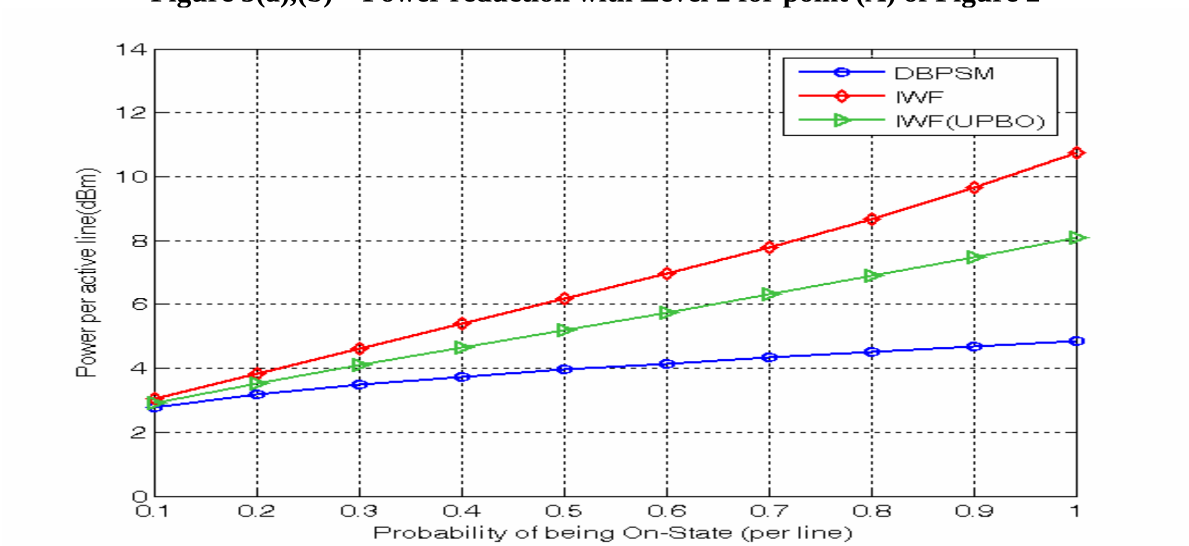

Figure 6 – Power reduction with Level 2 for point (B) of Figure 2

Figure 6 shows the power to achieve the higher data rate point (B) of Figure 2 than (A). In this case IWF with VN is not plotted because the point is not achievable.

Depending on which line is to be operated in L2 mode, the SMC can decide to turn MC on/off …

2.3 Reversion to weak algorithm from strong algorithm

If the DSL dynamics are severe and were not predicted correctly by the SMC (perhaps a poor or dysfunctional SMC), then a DSL modem should then (and only then) revert to the weak algorithm. If the strong algorithm can be maintained with the required target/minimum margin at the desired strong-user data rate, then it should be used.

During SHOWTIME, the bit-swapping mechanism will allow the user running the strong algorithm to return to the water-filling PSD if the noise is very severe. In this case, it is not the SMC's mistake but the actual noise variation that necessitates such a change. By responding properly to such a noise change, the DBP method allows achieving near-optimal performance unlike VN. The DBP method is better than IWF, or other existing methods such as VN or UPBO.

If there is local-loop unbundling (LLU) present, each service provider may optionally select to use Level 2 DSM and will not know the lengths of other service provider's users. That other service provider's user crosstalk is background noise in aggregately sensed and reported by the service provider's own DSLs, and thus used by the SMC. Each SMC makes its best decision based on the knowledge of only its own lines and the noise measured by its own lines. This SMC has the responsibility for predicting the dynamics of the binder and thereby ensuring acceptably low probability of outage.

3. References

[1] J.Cioffi, W. Lee, S. Jagannathan, and G. Ginis, "The Inherent Simplicity of Distributed Band Preference," *ATIS Contribution NIPP-NAI 2007-129R2,*Miami, FL, September 24, 2007.
[2] S. Jagannathan, C. S. Hwang, and J.Cioffi, "Margin Optimization in DSM Levels 1 and 2," *ATIS Contribution NIPP-NAI 2007-135R1,*Miami, FL, September 24, 2007.
[3] P. Silverman, G. Ginis, J. M. Cioffi, *An Indicator for 'Weak vs Strong' and 'Frequency Cutoff' for DSM Level 2,* ATIS Contribution, number unknown, Vancouver BC Canada, November 2007.
[4] Dynamic Spectrum Management Technical Report, "ATIS Committee NIPP Pre-published document ATIS-PP-0600007," May 2007.