ITU - Telecommunication Standardization Sector Temporary Document NG-097

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Question: 4/15

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TITLE: G.gen.bis: Considerations about the power penalty of Reed-Solomon forward Error Correction in ADSL systems in regard to the use of inner encoders.

ABSTRACT

Previous presentations (NF-084 and BM-087), provide theoretical and simulated results comparing the uncoded ADSL data stream with Reed-Solomon FEC, with Reed-Solomon plus Trellis and Reed-Solomon and multiple concatenated Convolutional Codes (MCCC).

In these presentations, the power penalty when using Reed-Solomon was not taking into account, because it did not affect the presentations' conclusions, namely, that the use of inner coding, whether Trellis or MCCC, with Reed-Solomon provides better performance than the use of only Reed-Solomon.

In this paper we present the mathematics for calculating the power penalty of error correction codes and apply this mathematics to Reed-Solomon FEC codes.

1. Introduction:

Previous presentations (NF-084 and BM-087), provide theoretical and simulated results comparing the uncoded ADSL data stream with Reed-Solomon FEC, with Reed-Solomon plus Trellis and Reed-Solomon and multiple concatenated Convolutional Codes (MCCC).

In these presentations, the power penalty when using Reed-Solomon was not taking into account, because it did not affect the presentations' conclusions, namely, that the use of inner coding, whether Trellis or MCCC, with Reed-Solomon provides better performance than the use of only Reed-Solomon.

In this paper we present the mathematics for calculating the power penalty of error correction codes and apply this mathematics to Reed-Solomon FEC codes.

2. Estimating the power penalty:

Error correcting codes are judged by their coding gain. The coding gain is the ratio of the inherent gain of the error correction codes over its power penalty. The power penalty results from the need to send a larger constellation which include the extra parity or check bits of the error correcting code.

The power penalty, for ADSL tone constellation, is defined as

[1] Contact: Juan Alberto Torres, Ph. D. E: jatorres@vocal.com
Frederic Hirzel E: fhirzel@vocal.com
Victor Demjanenko, Ph. D. E: victord@vocal.com
VoCAL Technologies, Ltd. T: +1(716) 688 4675
Buffalo, NY 14228, USA F: +1(716) 639 0713

$$\frac{2^{b'} - 1}{2^{b} - 1}$$

where *b* is the number of data bits and *b'* is the number of data bits plus parity or check bits. For example in the Trellis encoder of NF-084 one parity bit is required for every two tones (4-D Trellis encoding). This means *b'* is equal to *b+0.5* and the power penalty for this Trellis encode will be:

$$\frac{2^{(b+0.5)} - 1}{2^{b} - 1}\ 1$$

Of course this power penalty of the Trellis encoding was already included in the results of the previous presentations.

3. Application to the Reed-Solomon case:

Reed-Solomon codes also have a power penalty and this power penalty also depends on the number of bits per tone.

Let's assume that we have *K* octets and that we use *R* octets for Reed-Solomon FEC. In this case, the information bits are *8*K* and the total data is *8*(K+R)*, so *100*R/K=100*p* is the percentage of redundancy in our data stream, and the percentage of data information data is *(K+R)/K*100=(1-R/K)*100=(1-p)*100*.

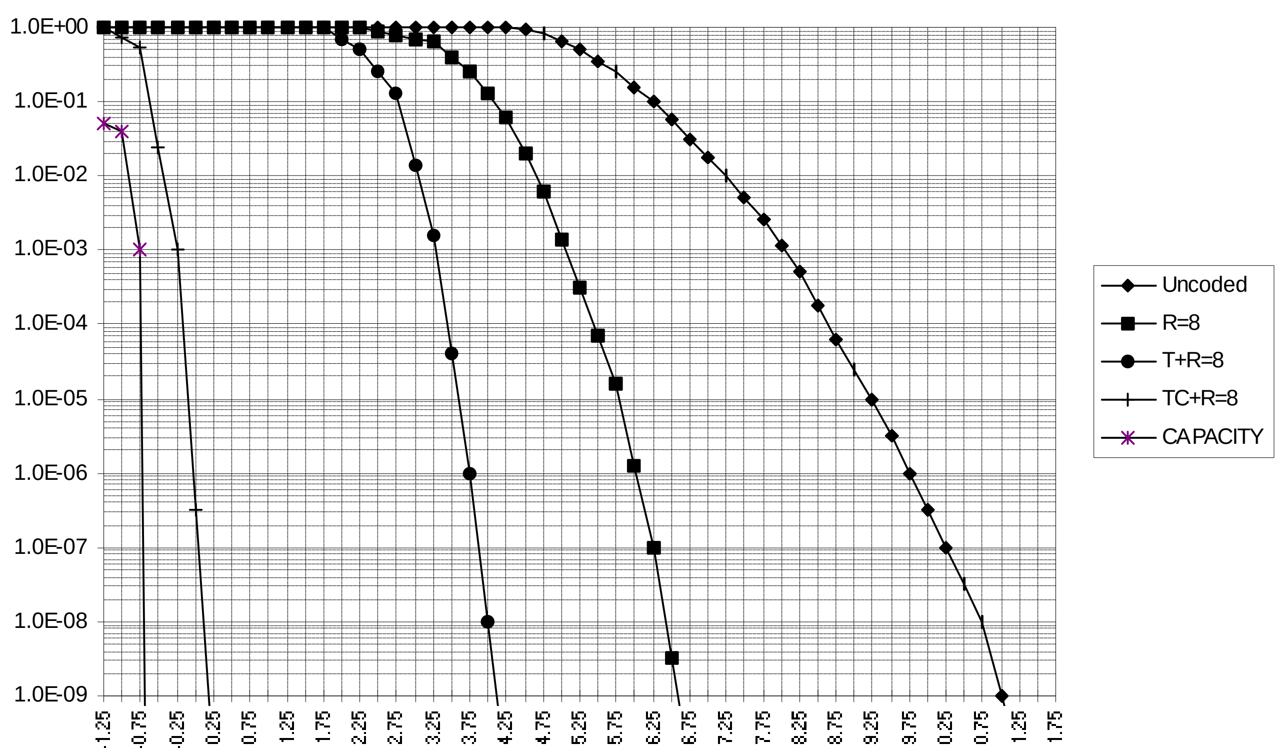
Ones *p* has been defined, we can define *b' = b (1 + p)*. The power penalty will then be as:

$$\frac{2^{\,b(1+p)} - 1}{2^{b} - 1}$$

For example, if we have *K=50* data octets and we use *R=8* check octets, *p=0.16*, and we need 16% more bits to transmit the additional 8 check octets.

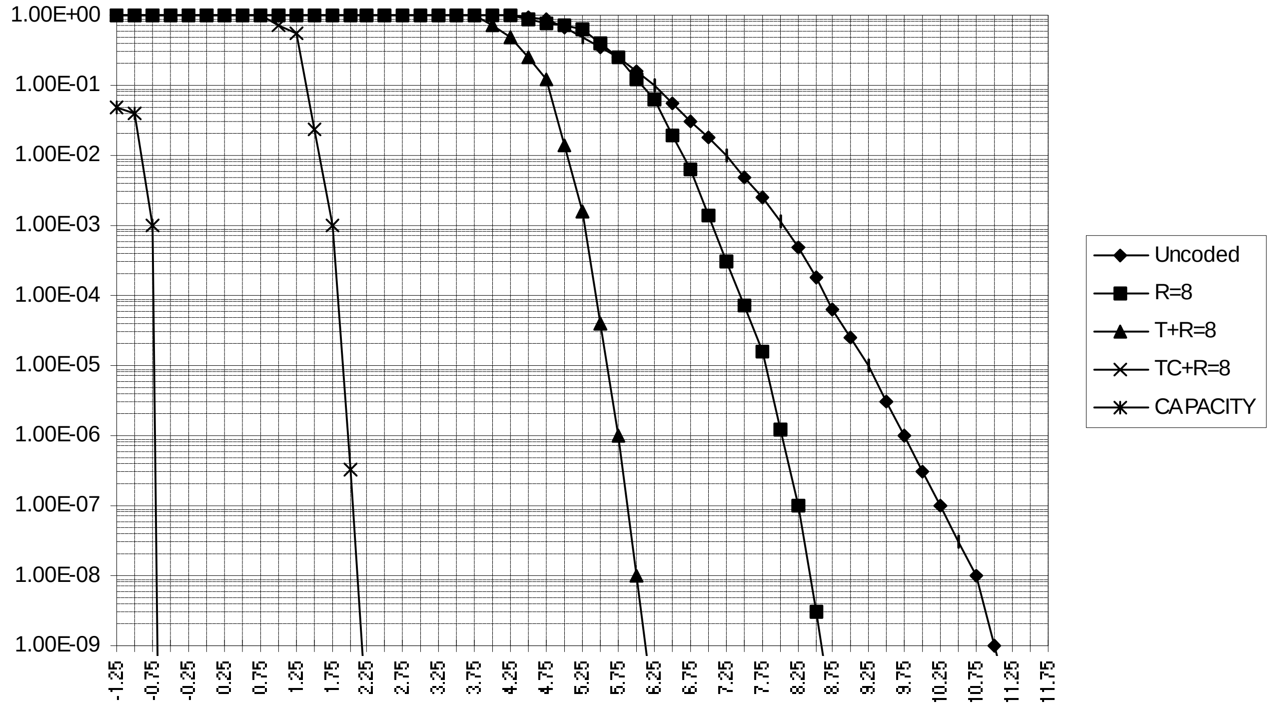
<u>Scenario A</u>

This scenario will represent the previous data presented previous presentations for *K=50* and *R=8*, the results for uncoded, Reed-Solomon, Reed-Solomon plus Trellis and Reed-Solomon plus MCCC were:



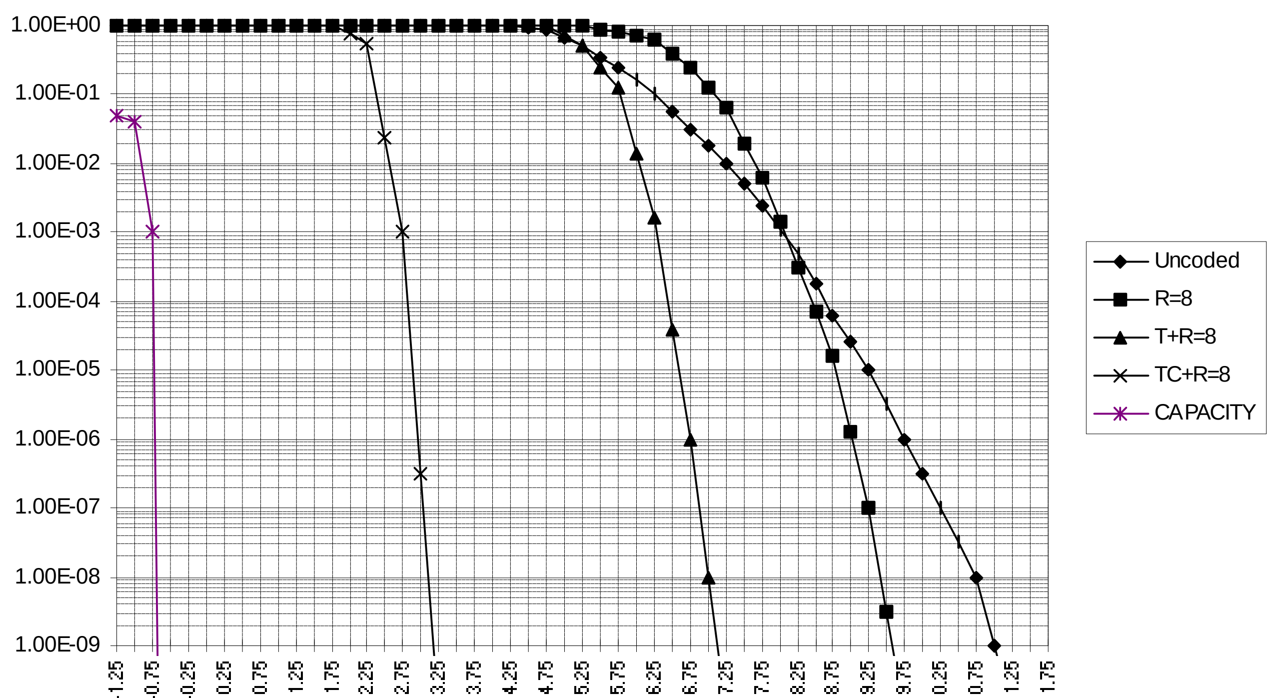
<u>Scenario B</u>

In this case, assuming a communication link of speed 1.6 Mbps. If we use 100 tones, the average number of bits per tone (using 4000 DMT symbols) will be 400/100=4 bits. For *b=4*, *R=8* and *K=50*, the power penalty of using The Reed-Solomon encoder will be 2 dB. So in this case all the curves, except the uncoded signal, will move closer to the uncoded signal by 2 dB



Scenario C

In this case, assuming a communication link of speed 4.8 Mbps. If we use 200 tones, the average number of bits per tone (using 4000 DMT symbols) will be 1200/200=6 bits per tone. For *b=6*, *R=8* and *K=50*, the power penalty of using a Reed-Solomon encoder will be 2.92 dB. So in this case all the curves, but the uncoded signal, will move closer to the uncoded signal by 2.92 dB.



4. Summary:

Previous presentations have provided theoretical and simulated results showing the advantages of Trellis and MCCC inner encoders. They neglected to include the power penalty of the Reed-Solomon encoding since it did not affect the conclusions of these presentations.

This presentation provides simulation results including the power penalty of the Reed-Solomon. These results confirm the conclusions of the earlier presentations.

In summary:

1. This paper shall be presented in G.dmt.bis “modulation and coding” and G.lite.bis “modulation and coding”.

2. We propose to the committee to a provisional agreement in the mandatory capability use of MCCC in G.992.1.bis and G.992.2.bis in the transmitter for manufacture interoperablity

5. References:

[1] NF-084. “Concatenated Trellis/Reed-Solomon Coding in DMT Systems”. Kschischang, Forney & Eyuboglu. Motorola, Nice France, 11-14 May 1998

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[3] AB-093. “G.gen: Use of Parallel Concatenated Convolutional Codes PCCC (Turbo-Codes) for G.dmt and G.lite”. V. Demjanenko, J.A.Torres, Antwerp, Belgium, 3-7 August 1998.

[4] AB-120. “G.dmt: Text to include an optional Parallel Concatenated Convolutional Codes (PCCC) in the draft G.dmt Recommendation”, V. Demjanenko, J.A. Torres. Antwerp, Belgium, 3-7 August 1998.

[5] T1E1.4/98-300. “ Text to include an optional Concatenated Convolutional Cede in ANSI T1.413 Issue2”. J.A. Torres, V. Demjanenko. San Antonio, Texas, August 31- September

[6] T1E1.4/98-301. “ Inclusion of Concatenated Convolutional Cede in ANSI T1.413 Issue2”. J.A. Torres, V. Demjanenko. San Antonio, Texas, August 31- September

[7] D.376 “Text to include an optional Serial Concatenated Convolutional Codes in the next version of G.dmt”. J.A. Torres, V. Demjanenko. Geneva, Switzerland, October 12-23 1998.

[8] PO-071. “G.dmt: Inclusion of a Serial Concatenated Convolutional Code in the G.992.1.bis”. J. A. Torres, V. Demjanenko. Sunriver, Oregon 18-22 January 1999.

[9] “Turbo Coding”. Chris Heegard, Stephen B. Wicker, Kluwer Academic Publishers, 1999.

[10] BM-087. “G.gen: Comparison of simulation results for different Coding Techniques (Uncoded, Reed-Solomon, Reed-Solomon plus Trellis and Reed-Solomon plus Parallel Concatenated Convolutional Codes) for G.992.1.bis and G.992.2.bis”. J. A. Torres, Frederic Hirzel, Victor Demjanenko. Boston 10-14 May 1999