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TITLE: 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

ABSTRACT

In this contribution VoCAL Technologies Ltd. proposes using Concatenated Convolutional Code technique for G.992.1.bis and G.992.2.bis recommendations. With this technique it is possible to reach longer loops (or works a higher bit rates in the same loop).

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1.- Introduction

In this contribution VoCAL Technologies Ltd. proposes using Concatenated Convolutional Code technique for G.992.1.bis and G.992.2.bis recommendations. With this technique it is possible to reach longer loops (or works a higher bit rates in the same loop).

With the use of the Trellis Coded Modulation (TCM) it is possible to obtain coding gains between 3 and 6 dB sacrificing neither data rate nor bandwidth. Using the technique that we propose, the performance is within 1 dB from the Shannon limit at a bit error probability of 10^{-7} for a given throughput, which improves the performance of all codes reported in the past for the same throughput.

In a Parallel Concatenated Convolutional Code (PCCC) the encoder is formed by two (or more) constituent systematic encoders joined through one or more interleavers. The input information bits feed the first encoder and, after having been scrambled by the interleaver, they enter the second encoder. A code word of a parallel concatenated code consists of the input bits to the first encoder followed by the parity check bits of both encoders.

PCCC achieves near-Shannon-limit error correction performance. Bit error probabilities as low as 10^{-5} at E_b/N_o=0.6 dB have been shown by simulations. Turbo Codes yield very large coding gains (around 10 or 11 dB) at the expense of a small data reduction, or bandwidth increase. In the PCCC case, after this value of 10^{-5}, the role of the interleaver is very critical and to avoid the floor-error it is necessary to make a good design of the interleaver. In our design the Reed-Solomon outer encoder take care of this floor-error below 10^{-7}.

In this document, we present simulation results, and we compare the Reed-Solomon encoder (for R=8 and R=16) with the Trellis plus Reed-Solomon (T+R=8 and T+R=16) and the Turbo-Codes plus Reed-Solomon (TC+R=8 and TC+R=16). All the theoretical results presented in document NF-084 had been verify with simulations in the laboratory.

These results are for Gaussian noise. In many wire-line systems, broadband impulse noise is also a significant transmission impairment. Although we have not modeled impulse noise effects in this analysis, in DMT systems, impulse noise whose duration is short compared to the frame size appears to be rather Gaussian-like, since it passes through a DFT in the receiver. Furthermore, because the noise is broadband, the noise energy in the signal band is distributed among the various frequency bins. Thus the additional immunity against additive white Gaussian noise provided by the trellis code should be beneficial for impulse noise as well.

The reason why we ask to include this Turbo-Code as optional in the standard is to allow manufacturer interoperability, due to the improvements that this technique achieve.

2.- Some History of Codification related with G.992.1

The actual optional codification proposed in the G.992.1 is based in part in the work by Forney in 1967 (Concatenated Codes). He introduced a concatenated scheme of inner and outer codes: the inner code is decoding using soft-decision channel information, while the outer Reed-Solomon code uses errors and erasures This technique have been proved to produce very good results, more in the out-space communications.

In 1993 a new coding and decoding scheme, dubbed Turbo codes by its discoverers, was reported, that achieves near capacity performance on additive white gaussian noise channel. This technique was based in the use of two concatenated Convolutional codes in parallel, this technique has two properties related with ADSL, first they have a floor error near 10^{-5} (ADSL specification is based in 10^{-7}) and the design of the interleaver in very critical to achieve good results in low BER (It is possible to avoid the floor error with an adequate design of the interleaver). This technique combined with a Reed-Solomon coding as outer encoder, had been used for out-space communications with a remarkable improvement with respect the trellis modulation. The Reed-Solomon encoder avoid the floor-error effect and made possible the use of the Turbo-Codes up to 10^{-7} without the effect of the floor-error.

3.- Parallel Covolutional Concatenated Codes

3.1.- Encoder

A PCCC encoder consists of two parallel concatenated recursive systematic convolutional encoders separated by an interleaver. The encoders are arranged in a “parallel concatenation”. The concatenated recursive systematic convolutional encoders are identical.

Figure 1 represents the proposed encoder, using a convolutional. A PCCC encoder is a combination of two simple encoders. The input is a block of information bits. The two encoders generate parity symbols (u_0 and u'_0) from two simple recursive convolutional codes. The key innovation of this technique is an interleaver "T" , which permutes the original information bits before input to the second encoder. The permutation allows that input sequences for which one encoder produces low-weight codewords will usually cause the other encoder to produce high-weight codewords. Thus, even though the constituent codes are individually weak, the combination is surprisingly powerful. The resulting code has features similar to a "random" block code.

In this way, we have the information symbol (u_1) and two redundant symbols (u_0 and u'_0). With this redundancy it is possible to reach longer loops, or works a higher bit rates in the same loop, at the cost of a slight increase of the constellation encoder .

The reason we suggest the use two 1/2 convolutional encoders in parallel, is that this simplify the Turbo-code encoder and it still produces results very close to the channel capacity. The use of two 2/3 convolutional encoders in parallel will produce a little better results (in the order of 0.1 or 0.2 dB) and will increase the complexity at least by four. From a practical point of view VoCAL Technologies thinks that is not appropriate.

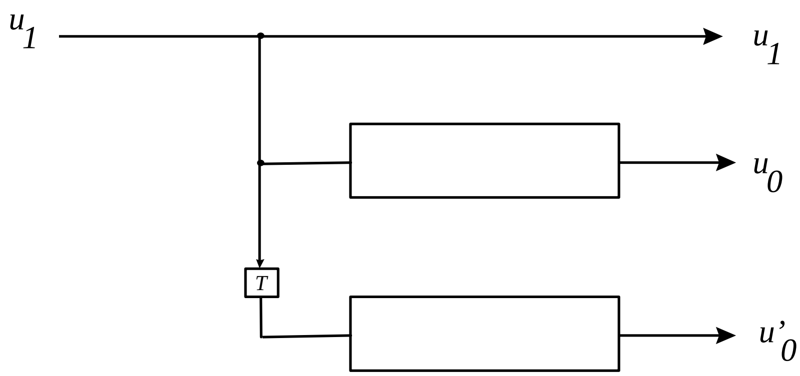

Figure 1. Parallel Convolutional Concatenated Encoders

In the figure 2 we have presented the conversion that we propose, taking into account the new parity bit.

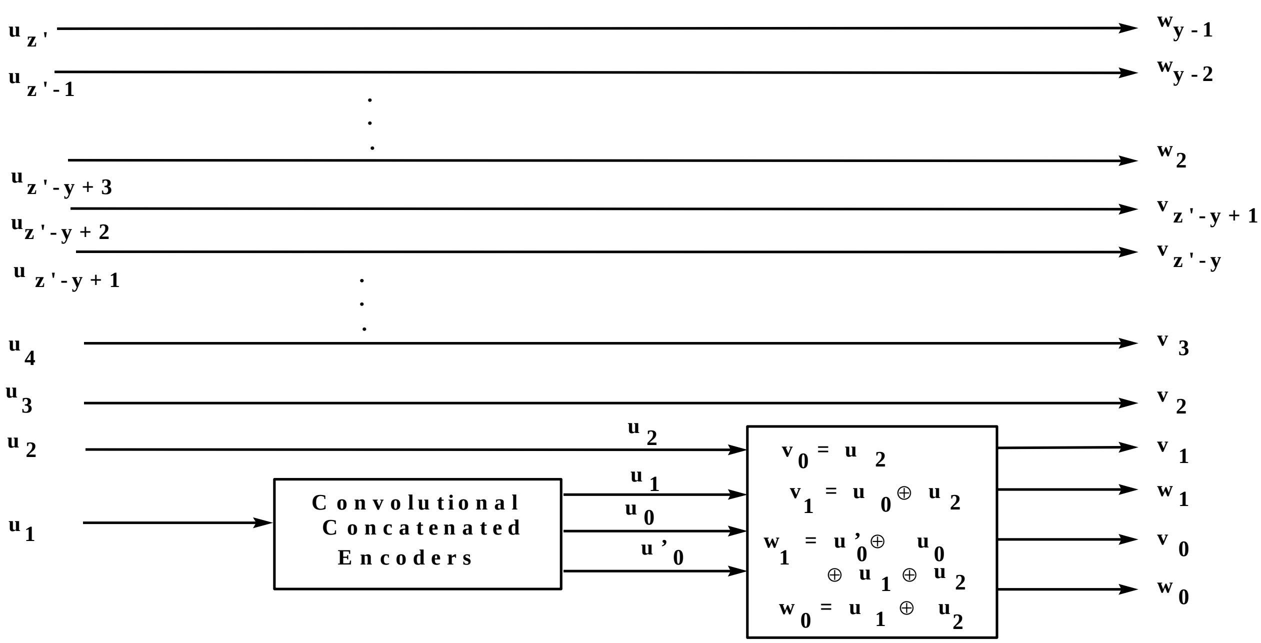

Figure 2.- Conversion of u to v and w

3.2.- Simulations

Simulations with two equal, recursive convolutional consistent codes with an interleaver of length 400 and K=50. With this value the delay is below 5 msec for 1.5 Mbit/s assuming a delay of 3 interleaver.

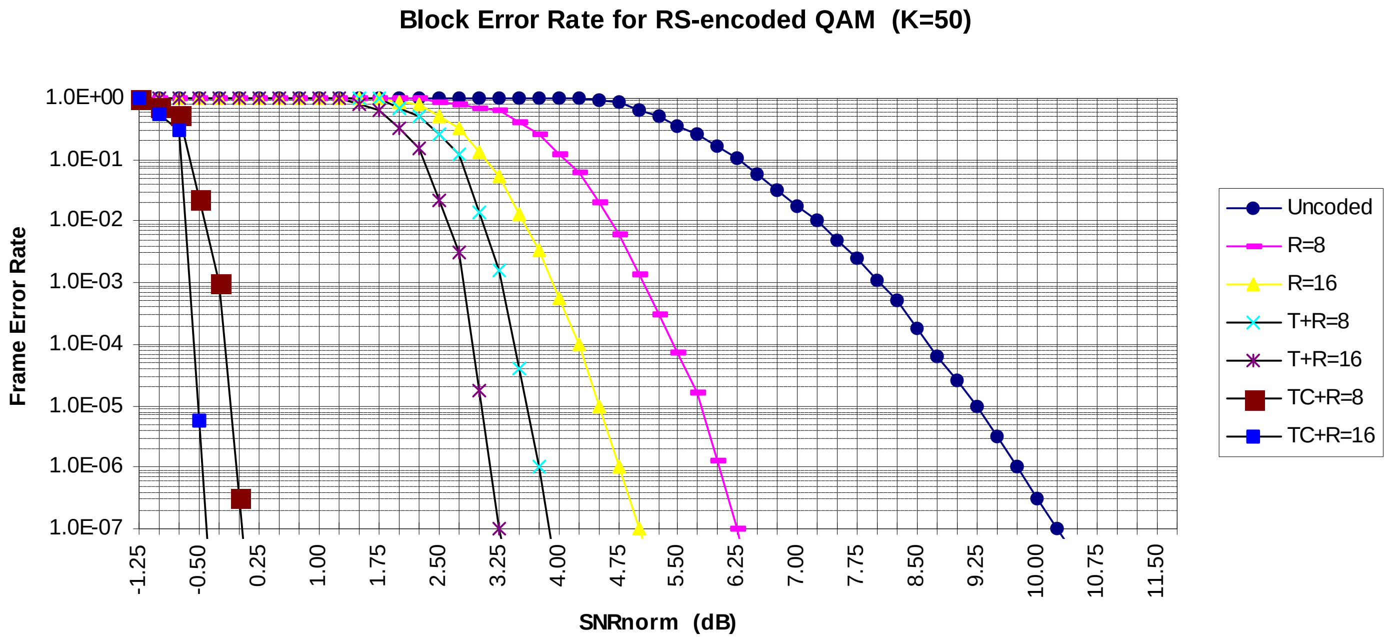

Figure 3.- Simulations for PCCC

In the TC case the number of Iterations are always below 10.

4.- Conclusion

We propose that G.992.1.bis and G.992.2. use CCC as an option. The reason to include in the standard is to allow manufacturer interoperability, due to the improvements that this technique achieve, over 3.5 dB over the Trellis Codification Modulation.

5. Summary

We recommend that G.992.1.bis and G.992.2.bis have the potion of use of CCC to reach longer loops or increase the troughput of the system.

1. Agenda Item: G.992.1.bis and G.992.2.bis.
2. Expectations: The committee accept as optional in the G.992.1.bis and G.992.2.bis the procedure described in this paper.

6. References

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