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TITLE: G.gen: Comparison between coset "tone-base" turbo codes and "bit-base" turbo codes

ABSTRACT

This paper describes a comparison of proposed coset "tone-base" turbo codes and proposed "bit-base" turbo codes for G.992.1bis and G.992.2bis error correction. Using three criteria, complexity, latency, and performance, we show that the proposed "bit base" turbo codes are superior to proposed coset "tone-base" turbo codes.

1. Introduction.

VOCAL Technologies is familiar with both coset "tone-base" turbo codes and "bit-base" turbo codes for G.992.1bis and G.992.2bis error correction. VOCAL Technologies has contributed papers for both types of turbo codes. VOCAL Technologies favors "bit-base" turbo codes such as those proposed in BA-020.

Any practical G.992.1bis and G.992.2bis error correction proposal must primarily be implementable, have low well-characterized latency, and have good performance for all types of line impairments. In order to compare coset "tone-base" turbo codes with the "bit-base" turbo codes we considered the following requirements:

Computational Complexity.
Latency Characteristics.
Performance.

2. Computational Complexity.

Initially it would appear that coset "tone-base" turbo codes have much less computational complexity than "bit-base" turbo codes. Detailed analysis of the maximum computational burden reveals both turbo codes have essentially the same computational complexity.

The computational complexity of a MAP, MAP-log or MAX MAP-log decoder depends on the number of iterations, the number of states, and number of allowable state transitions. We expect the coset "tone-base" decoder and the "bit-base" decoder to require the same number of iterations. The proposed coset "tone-base" turbo code and the proposed "bit-base" turbo code have the same number of states. The coset "tone-base" turbo code, though, has twice as many allowable state transitions as the "bit-base" turbo code. The difference is due to the use of the coset "tone-base" 2/3 constituent encoder opposed to the "bit-base" 1/2 constituent encoder. For this reason the coset "tone-base" decoder has twice the burden of the "bit-base" decoder.

On the other hand, the "bit-base" turbo code has a maximum rate of 6144 kbit/second and the coset "tone-base" turbo code has a maximum rate of 1024 ktone/second. For this reason the "bit-base" decoder has six times the burden of the coset "tone-base" decoder.

When both these results are combined, the maximum computational burden of the proposed "bit-base" turbo codes are only 3 times that of the proposed coset "tone-base" turbo codes.

[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
F: +1 716 639 0713

3. Latency Characteristics.

The latency of using a turbo code is determined directly from the length of the interleaver required by the turbo code. Though coset "tone-base" turbo codes and "bit-base" turbo codes both use interleavers, the basic structural difference of the codes, tone versus bit, yields superior latency characteristics from "bit-base" turbo codes.

3.1 Latency versus performance.

Given a coset "tone-base" turbo code operating with a given interleaver size, a "bit-base" turbo code can either operate:

1) With at most one half the latency and the same performance; or
2) With the same latency and better performance.

This superior latency characteristic is a direct consequence of the basic DMT structure, namely, there is at least two bits per tone. If the "bit-base" interleaver is the same length as the coset "tone-base" interleaver, it will span no more than half as many tones. If the "bit-base" interleaver spans the same number of tones as the coset "tone-base" interleaver, the "bit-base" interleaver will be no less than twice the length of the coset "tone-base" interleaver.

3.2 Latency versus data rate.

For a given data rate and interleaver size, "bit-base" turbo codes will always have the same latency. This cannot be guaranteed for coset "tone-base" turbo codes. For coset "tone-base" turbo codes, if there are more bits per tone, the latency increases; if there are less bits per tone, the latency decreases.

4. Performance.

Any proposals for G.992.1bis and G.992.2bis error correction should perform well for the most common operating conditions and under the most common impairments. As a minimum, the error correction should perform well encoding a variety of bits per tone, and perform well under both white and impulse noise conditions.

4.1 White noise performance with two bits per tone.

Both the coset "tone-base" turbo codes and the "bit-base" turbo codes perform equally well under white noise when transmitting two bits per tone. Performance is near Shannon for the given QAM constellations with equivalent interleaver sizes.

4.2 White noise performance with many bits per tone.

When many bits per tone is required, "bit-base" turbo codes performance is clearly superior over that of coset "tone-base" turbo codes. While the "bit-base" turbo codes continue to exhibit near Shannon performance, coset "tone-base" turbo codes increasingly deviate from this limit as the number of bits per tone is increased.

The reason for the superior performance of the "bit-base" turbo codes is straightforward from the structure of the coding scheme: all bits are encoded for "bit-base" turbo codes while only two bits are ever encoded for coset "tone-base" turbo codes.

4.3 Impulse noise performance.

VOCAL has no reason to believe the impulse noise performance of the "bit-base" turbo code will be any less than that of coset "tone-base" turbo codes.

5. Summary

For the reasons presented in this paper, "bit-base" turbo codes are superior to coset "tone-base" turbo codes. They have similar computational complexity, superior latency characteristics, similar performance for two bits per tone and superior performance for several bits per tone, and similar impulse noise performance. The "bit-base" turbo code has a higher Net Coding Gain than the coset "tone-base" turbo code, a lower floor error than the coset "tone-base" turbo code and is expected to have at least the same burst error statistics than the coset "tone-base" turbo code

This paper addresses point 4 of G.992.1.bis issues list and point 1.4 of G.992.1.bis issues list.

VOCAL Technologies proposes that G.992.1.bis and G.992.2.bis support "bit base" turbo codes as described in BA-020 for Forward Error Correction.