Channel Codes That Exploit the Residual Correlation in CELP-Encoded Speech[1]

Fady Alajaji†, *Nam Phamdo*‡ and *Tom Fuja**

† Department of Mathematics and Satistics, Queen's University, Kingston, Ontario K7L 3N6, Canada

‡ Department of Electrical Engineering, State University of New York, Stony Brook, NY 11794-2350, USA

* Department of Electrical Engineering, University of Maryland, College Park, MD 20742, USA

Abstract — **This paper describes methods by which the residual correlation in CELP-encoded speech can be exploited by an appropriately designed channel decoder. Specfically, the LSP redundancy in FS 1016 CELP is quantified and used to effect near-MAP decoding of Reed-Solomon and convolutional codes. Coding gains of up to 3.5 dB are obtained over conventional ML algorithms.**

Summary of Results

We consider the problem of reliably transmitting speech compressed with codebook-excited linear predictive (CELP) coding over a noisy channel. The particular implementation we consider is Federal Standard 1016 4.8 kbit/s CELP.

Like all practical speech encoders, CELP does not eliminate *all* the redundancy in speech samples; what remains is the "residual redundancy". In this work, we consider methods by which channel codes can use this redundancy to enhance the performance of CELP-encoded speech over very noisy channels. Specifically, we describe ways the residual redundancy in CELP's line spectral parameters (LSP's) can be quantified and exploited. We begin by proposing two models for LSP generation; the first model incorporates only the non-uniformity of the LSP's and their correlation within a CELP frame, while the second provides for correlation between frames as well. When these models are "trained" using an actual CELP bitstream they show that as many as 12.5 of the 30 high-order LSP bits in each frame may be redundant.

We next present decoding algorithms that exploit that redundancy via both convolutional and Reed-Solomon codes. For convolutional codes, we employ three soft-decision decoding schemes, all based on the Viterbi algorithm:

- ML – the "usual" maximum likelihood algorithm;
- MAP 1 – a MAP algorithm that exploits the redundancy due to the non-uniformity of the LSP's and their correlation *within* a frame – about 10 bits/frame;
- MAP 2 – which exploits the redundancy from the non-uniform distribution of the LSP's and their correlation within *and between* frames – about 12.5 bits/frame.

For block codes, we present four soft-decision decoding (SDD) algorithms:

- SDD 1 – which approximates "traditional" maximum likelihood decoding and does not attempt to exploit any of the residual redundancy;
- SDD 2 – which exploits only the redundancy due to the ordered nature of the LSP's – about 4.4 bits/frame;
- SDD 3 – which like MAP 1 exploits the redundancy due to the non-uniform distribution of the LSP's and their correlation within a frame;
- SDD 4 – which like MAP 2 exploits both the inter- and intra-frame correlation and the redundancy due to the non-uniform distribution.

Figures 1 and 2 display the simulated performance of these decoders in terms of average spectral distortion; the channel is AWGN and the modulation is BPSK. Clearly, MAP 2 and SDD 4 provide exceptional performance at very low E_b/N_0.

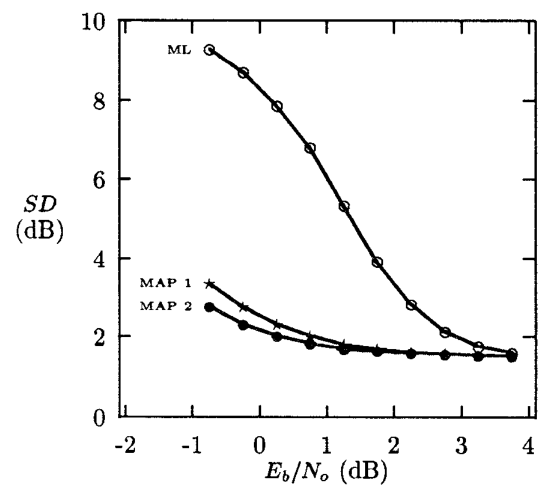

Fig. 1: Average spectral distortion – convolutional code.

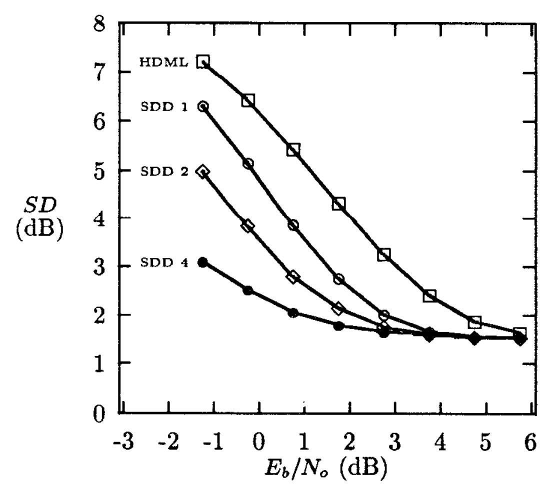

Fig. 2: Average spectral distortion – Reed-Solomon code. (HDML = hard-decision ML.)

[1]The work of Alajaji and Fuja has been supported by the U.S. Department of Defense under grant MDA 904-94-3008. The work of Phamdo has been supported by NTT Corporation.