Coupled Receiver-Decoders for Low Rate Turbo Codes

Jon Hamkins, Dariush Divsalar[1]
Communications Systems and Research Section
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA
email: {hamkins, divsalar}@jpl.nasa.gov

Abstract — **We present a rate 1/31 turbo code that achieves a bit error rate of 10^{-6} at $E_b/N_0 = -0.9$ dB. At this coding gain, insufficient energy per symbol is present for a conventional receiver to recover the carrier phase properly. We present a method to overcome this problem by coupling the receiver and decoder functions. Simulations indicate that this approach may enable the elimination or significant reduction of required residual carrier power for signaling on AWGN channels impaired by phase noise.**

I. A rate 1/31 turbo code

We have designed a rate 1/31 turbo code that achieves BER=10^{-6} at E_b/N_0 = -0.9 dB. This is competitive with the best codes of similar rate and blocklength; an additional 0.2 to 0.3 of coding gain has been shown to be possible by using a lower rate, a longer interleaver, and more decoding iterations (see, e.g., turbo-Hadamard codes [PLW01]). The first component code has feedback $1 + D^2 + D^5$, or 45 in octal notation, and the second has feedback $1 + D$, or 3. The 15 feed-forward connections for the component codes are identical: {41, 43, 47, 51, 53, 55, 57, 61, 63, 65, 67, 71, 73, 75, 77}. Together with the systematic bit, there are 31 outputs per input bit. Simulated performance is within 0.6 dB of the unconstrained capacity of rate 1/31 codes, -1.494 dB, and was obtained for a code with input block size 16384, decoded with a log-MAP turbo decoder using 20 iterations.

A receiver must acquire the carrier phase prior to decoding. A conventional Costas loop accomplishes this, but even in the absence of phase noise it incurs a squaring loss of $\frac{E_s/N_0}{1+2E_s/N_0}$, where E_s/N_0 is the symbol energy to one-sided noise PSD ratio. The rate 1/31 turbo code operates at BER=10^{-6} at $E_s/N_0 = -15.8$ dB, which unfortunately results in a squaring loss of 13.0 dB. Without a better receiver, power would need to be diverted from the telemetry signal and put into an unmodulated residual carrier.

II. A Coupled system for carrier tracking and decoding

A joint phase-and-data recovery process is used on each of the constituent convolutional codes of the turbo code, using per-survivor processing (see Figure 1). Although the component codes are individually weak, they are strong enough to allow adequate phase recovery from the suppressed carrier signal. Thus, the quality of the soft input in the first iteration of the turbo code is adequate enough for the turbo decoder to provide improved feedback to the receiver. Additionally, since the complexity of the constituent codes is quite small individually, this joint receiver-decoder approach has low complexity as well.

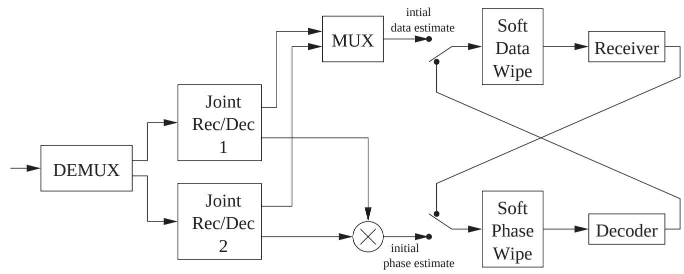

Figure 1: A coupled receiver-decoder for suppressed carrier signals.

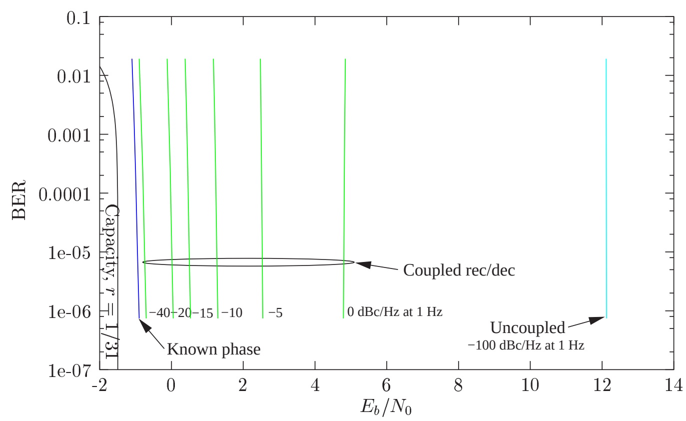

Figure 2: Performance of the coupled receiver-decoder in presence of phase-noise and AWGN.

Figure 2 shows the performance of this coupled receiver-decoder on an AWGN channel impaired by phase noise with a two-sided PSD $S(f)$ proportional to $1/f^3$, ranging from $10\log_{10} S(1) = -100$ to 0 dBc/Hz. At -100 dBc/Hz., performance was indistinguishable from the ideal case of known phase, and 13 dB better than the uncoupled system using a Costas loop. A moderately high phase noise of -20 dBc/Hz resulted in about a 1 dB loss from the ideal performance.

[1]The work described was funded by the IPN Technology Program and performed at the Jet Propulsion Laboratory, California Institute of Technology under contract with the National Aeronautics and Space Administration.

References

[PLW01] L. Ping, W.K. Leung, and K.Y. Wu. Low rate turbo-Hadamard codes. In *IEEE Int. Symp. Inform. Theory*, page 211, 2001.