Abstract - This paper determines the performance of the Turbo coding technique using M-ary (M = 2, 4, 8) differentially coherent and non-coherent modulation schemes in both a non-fading and a Rayleigh fading environment. The constituent codes are convolutional and the specific modulation techniques include Differential Phase Shift Keying (DPSK), Double Differential Phase Shift Keying (DDPSK), and non-coherent detection of Frequency Shift Keying (FSK). Note that these modulations are all constant envelope, which is a desirable characteristic for hard limited channels such as transmission over satellite transponders. The emphasis is on constructing modulation/Turbo coding schemes that perform at a lower required Eb/No and greater bandwidth efficiency than current coding approaches that use these modulation techniques. The Turbo coding approaches developed in this paper require a small interleaver delay (to allow use in packet transmission systems with packet sizes ranging up to about 2048 bits) and a low number of decoding iterations for processing the constituent codes. They are robust in AWGN and Rayleigh fading channels, relatively easy to implement, and power and bandwidth efficient.

SUMMARY

The Turbo coding technique introduced in 1993 by French researchers [1] has achieved impressive performance in approaching the Shannon limit with moderate decoding complexity and decoding delay. The particular Turbo code design described in that paper used a parallel concatenation of two rate 1/2 recursive systematic convolutional codes with puncturing to achieve an overall code rate of 1/2. The two constituent codes were serially decoded in an iterative fashion using soft-in, soft-out Maximum A Posteriori Probability (MAP) decoding and the modulation was coherent antipodal signaling on an Additive White Gaussian Noise (AWGN) channel. This code achieved a bit error probability of 1E-5 at an Eb/No = 0.7 dB using 18 decoder iterations, which is about 0.7 dB away from channel capacity.

The modulation techniques proposed here are not coherent and are independent of the initial phase of the received symbols. The use of differentially coherent and non-coherent modulation eliminates the need for a coherent phase reference at the receiver, which is sometimes difficult or impossible to achieve, especially on fading channels or channels with significant Doppler frequency present. The advantage of DDPSK modulation is that the demodulation performance is invariant to a constant Doppler offset. As in non-coherent FSK, the only loss due to Doppler is a sin(x)/(x) loss. In a severely fading environment (especially where the fading decorrelation time approaches the symbol time), the only characteristic of the transmitted signal to survive is the frequency. Under these conditions, M-ary FSK modulation with Turbo Coding provides a reasonable modulation/coding solution.

Simulations were performed with DPSK modulation and a R=1/3 parallel concatenation of two R=1/2 systematic recursive convolutional codes using the Soft Output Viterbi Algorithm (SOVA) as defined by Hagenauer et. al. [2]. Four and eight state Constituent Codes (CC) defined in [3] were used in AWGN with a packet size of 1023 bits and pseudo random interleaving between the two codes. The interleaver is implemented with a Linear Sequence Generator (LSG) defined by a primitive polynomial. The state of the LSG defines the interleaving addresses. A Bit Error Probability (BEP) of 1E-5 was achieved in AWGN at an Eb/No = 6.5 dB and 5.8 dB for the four state and eight state CCs, respectively, with six decoding iterations. The four state CCs achieved a BEP of 1E-5 at Eb/No = 9.3 dB in Rayleigh fading assuming perfect interleaving and no side information.

In this paper, the computational cut-off rate R_0 and the channel capacity C for M-ary DPSK, DDPSK, and FSK is compared to the Turbo Coding performance. The channels assumed include AWGN and Rayleigh fading over a range of decorrelation times from many times the symbol interval to a small fraction of the symbol interval. The size and type of interleavers required for a desired performance, given the modulation, coding, and channel characteristics, are determined. Finally, various soft-in, soft-out decoding algorithms (MAP, SOVA) are investigated and analyzed to provide an efficient, easily implemented, decoding procedure requiring few decoding iterations.

REFERENCES


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