CONVOLUTIONAL CODING FOR MULTIPLE-ACCESS SATELLITE COMMUNICATION

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Summary Convolutional Coding with Viterbi Decoding, using a rate 1/2 constraint length 7 code, provides a 5 dB improvement in power-limited satellite communication if care is taken with tracking loops. Use with FDMA typically requires ambiguity resolution and differential encoding-decoding with one decoder and one demodulator per access. Time-sharing of one demodulator and decoder among several accesses is possible with TDMA if an aggregate rate buffer is provided and if control and timing loops are digitized, stored, and updated once per frame. A possible system is outlined.

Coding Gain The advantages of convolutional encodingViterbi decoding on a low bit error rate communication system utilizing binary phase-shift-keyed (BPSK) or quadriphaseshift-keyed (QPSK) modems with high signal-to-noise ratio tracking loops is now well documented (1). At bit error rates of 10^{-5}, an improvement of 5 dB or greater on an approximately Gaussian channel is obtained by the introduction of a constraint length 7, rate 1/2 convolutional-code combined with soft decision decoding. Above 2Ghz, satellite channels appear Gaussian and the full coding improvement can be realized, bandwidth permitting, if care is given to provide high signalto-noise ratios in the phase tracking loop, 18 dB sufficing for BPSK and 24 dB for QPSK. There is even some evidence that actual coding gain is greater, since certain modems, especially those with highly digital implementations, operate closer to theoretic at the low symbol signal-to-noise ratios used with coding than they do at the higher (bit) signal-to-noise ratios required without coding.

Use with FDMA The introduction of coding into a frequency division multiple access (FDMA) satellite communication system is straightforward with a convolutional coder preceeding each modulator and a Viterbi decoder following each (soft-decision) demodulator. Such systems usually utilize a form of Costas loop phase tracking with a resulting two-way (PSK) or fourway (QPSK) phase ambiguity. In BPSK, rate 1/2 codes also have a node synchronization ambiguity since the two check bits are interleaved serially in time on one data stream rather than being placed on separate data streams as possible in QPSK. In each case, the 180° ambiguity can be resolved by use of a transparent convolutional code with a differential coder preceeding the convolutional encoder and a differential decoder following the Viterbi decoder. The transparent code permits proper decoding of code word complements as well as code words. The differential decoder increases bit error probability less than 25% above that at the decoder output (1), since the errors are not independent, and thus causes less than 0.1 dB degradation. The second ambiguity in each case is resolved by trying the second possibility, shifting branch framing 1 symbol for BPSK and effectively changing phase by $\pi/2$ for QPSK after extended periods of bad data, as determined by monitoring metric increase within the decoder. In general, the total cost of ambiguity resolution is about 0.1 dB as opposed to greater than 0.3 dB in the uncoded system.

Use with TDMA The application of coding to a time division multiple access (TDMA) satellite communication system in general requires more care. In a TDMA system, time is broken into frames with frame durations depending on the system but perhaps a millisecond in duration. Transmitters are assigned bursts within each frame (on an as-needed basis for demand-assignment systems) and subbursts within the burst for traffic intended for various receivers. Thus, a receiver must be able to demodulate several subbursts, one per active access, selected from various positions within the frame. The data rate within these subbursts may be quite high, for example 80 Mbps.

The introduction of convolutional encoding with Viterbi decoding into a TDMA system has been discussed previously (2). Two considerations have major impact upon the design. First, it is cost-effective to time-share as much of the hardware, including the decoder, as possible rather than pro viding a modem and decoder per access as typically done in FDMA. Second, it is undesirable to decode subbursts at the burst rate, since decoders capable of operation at data rates up to 80 Mbps are feasible but very expensive. Commercial decoders are available at data rates up to 8 Mbps at reasonable cost. Jacobs and Sims (2) discuss this problem in detail and suggest the use of station-aggregate rate decoding with the decoder required to operate only as fast as the sum of the user data rates accessed by the terminal, perhaps a few Mbps maximum. The subbursts are smoothed into a single aggregate rate data stream by an aggregate-rate expansion buffer prior to decoding. Data streams are separated into individual user streams, one per access, after decoding, and further smoothed in.a user rate expansion buffer.

Phase ambiguity and node synchronization are not usually a problem in TDMA since timing must be known quite precisely at the receiver to separate bursts. A preamble is usually used to provide energy for phase and bit timing tracking loops and for a synchronization word and bit stuffing channel. The decoder in a TDMA system does not provide ambiguity resolution. To time share the decoder, each subburst may be tailed off with a known sequence, typically all 0’s.

TDMA Receiver Functions Figure 1 shows a possible TDMA receiver functional block diagram. Various control signals and data paths are indicated on the figure. The receiver burst timing and control unit informs the burst demodulator when preambles occur, permitting loops to lock and settle. If a single burst rate is utilized, all subbursts are demodulated. The aggregate rate buffer accepts selected demodulated subbursts at burst rate and outputs to the Viterbi decoder whenever one of two alternating buffer registers is filled. The selected subbursts are specified by a START-OF-SUBBURST (SOS) bit and an identifier (ID) code. The aggregate rate buffer must store 6 bits of data per information bit for a rate 1/2 code and a 3-bit soft decision modem, as well as the SOS bit and ID bits. The decoder output is fed to the baseband rate buffer and subbursts separated with the aid of ID/SOS (identification/start of subburst) control bits which pass through ‘ the aggregate-rate buffer and a delay line equivalent to the decoder prior to entering the aggregate rate control unit., After separation of subbursts, data is placed in appropriate locations in the user buffer and clocked out to the users. Timing is provided by loops which act to keep the user buffer half filled.

The structure of the system is such that almost all functions including timing, control, and various loop calculations can be time-shared in special purpose (microprogrammed) computers with operating calculations performed rather leisurely once per frame. Most components of the system are unaffected by the presence of the decoder except for the separation of buffering into both aggregate rate and user rate pieces and the requirement that the aggregate rate buffer store 6 bits of data per information bit.

References

1. I. M. Jacobs and J. A. Heller, “Viterbi Decoding for Satellite and Space Communication,” IEEE Transactions on Communication Technology, Vo. COM-19, No. 5, Part III October, 1971.

2. I. M. Jacobs and Capt. R. J. Sims, “Configuring a TDMA Satellite Communication System with Coding.” Conference Proceedings of the Fifth Hawaii International Conference on System Sciences, Honolulu, Hawaii, January, 1972.

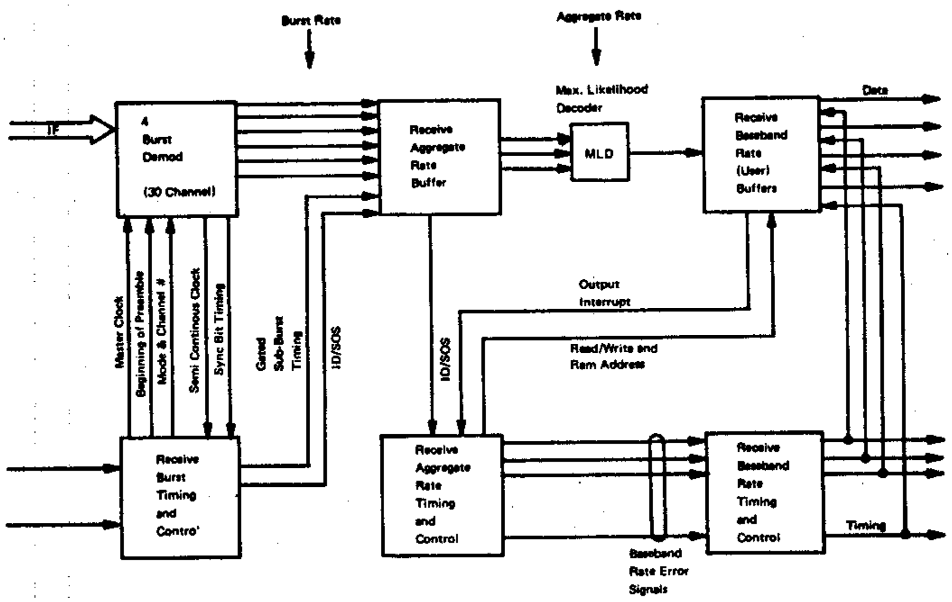

Figure 1. TDMA Receive Functional Block Diagram