

# Reed-Solomon Concatenated Codes

## Industry Requirements

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The commercial satellite industry is always searching for methods to improve error rate performance because this translates into either reduction of power usage in the spacecraft or reduction of Gain over Temperature (G/T) from the receiving system. Comtech EFData's first experience in this area was in conjunction with Eutelsat.

Eutelsat was desirous of transmitting two channels of High Definition Television (HDTV) to sites in Europe where the largest antenna permitted was 2.4 meters. Standard error correction methods required in excess of 3.0 meter antennas. Comtech EFData was able to satisfy the requirement by using two error correction codes. The resulting modem, the SDM-70, provides two channels of 34 Mbit/s, and due to the reduction in required  $E_b/N_0$ , was able to be used with a 2.4 meter antenna.

Intelsat has also been a driving force in concatenated error correcting codes. The strategy for Intelsat was to provide superior performance at the same G/T for an existing system. Concatenated error correcting codes are now accepted by Intelsat and defined as an optional mode of operation in the open network system.

## Theory

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Convolutional encoding with Viterbi decoding has been in use for many years in commercial satellite systems. A characteristic of the Viterbi decoding process is that as the  $E_b/N_0$  becomes increasingly smaller, the uncorrectable errors that are passed through the system are clumped together. Although the distribution of errors caused on the link are Gaussian, the uncorrectable error distribution looks like one found on a classical bursty channel. A class of codes that are well known to correct bursty errors is the Reed-Solomon code. The obvious conclusion is to concatenate the Viterbi and Reed/Solomon codes. Comtech EFData was the first company to provide IESS-308 Rev. 6B equipment. Comtech EFData provides both new second generation hardware with the option, as well as upgrade kits for older first generation equipment.

## Implementation

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The addition of the outer code causes an increase of 12.5% of bandwidth for Intelset Business Services (IBS), and from 8 to 10% increase for Intermediate Data Rate (IDR). This poses no problem for variable rate filters. However, modems equipped with fixed rate filters must be either at the normal inner code rate or the outer code rate. Since the outer code must be able to be switched in and out with no degradation to the inner code performance (see Figure 1), fixed rate filters will not be replaced. This action allows normal Bit Error Rate (BER) performance when using the normal Viterbi-only mode, and 0.2 to 0.4 dB degradation when in the concatenated mode. Since the coding gain is large for concatenated coding, the slight loss is acceptable.

The terrestrial interface consists of a double board. The Reed-Solomon function is realized by providing a re-designed top board that includes the additional framing, interleaving, and codec processing. Only a screwdriver is required to separate the two boards and install the new top board. Monitor and control firmware must also be replaced.

## Performance

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The attached graphs (Figures 2, 3, and 4) show the expected performance improvements for concatenation of 1/2 rate, 2/3 rate, and 3/4 rate Viterbi codes concatenated with the Reed/Solomon code for modems back-to-back with additive Gaussian noise. The 2/3 and 3/4 rates are achieved by puncturing the 1/2 rate convolutional code. The constraint is standard  $K=7$ .

## Ordering Information

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Comtech EFData has implemented the concatenated codes in its standard IDR and IBS modems by providing a field upgrade kit. To order a new modem with this feature, specify this option at the time of order. In order for the sales department to identify and price the correct kit, the following information must be provided:

1. Model number
  - a. SDM-300
  - b. SDM-8000
  - c. SDM-9000
  - d. SLM-8650
2. Serial number
3. Firmware version (found on two chips in M&C board)
4. Symbol filters, variable or fixed

A field upgrade kit will be provided for the unit, complete with step-by-step instructions. No special tools are required besides a chip puller and screwdriver. The kit consists of a new terrestrial interface top board, two M&C chips, and instructions.

The SDM-8000, a second generation combination IBS/IDR modem, can be ordered with the concatenated code option. The option is provided by a small daughter card that plugs on the top of the SDM-8000 interface card, and it can be installed with a screwdriver. To order the field installable option, the following information must be supplied with the order:

1. SDM-8000
2. Serial number
3. Options in the modem

There is no upgrade kit for the SDM-70, as it is only supplied with the concatenated codes already built-in.

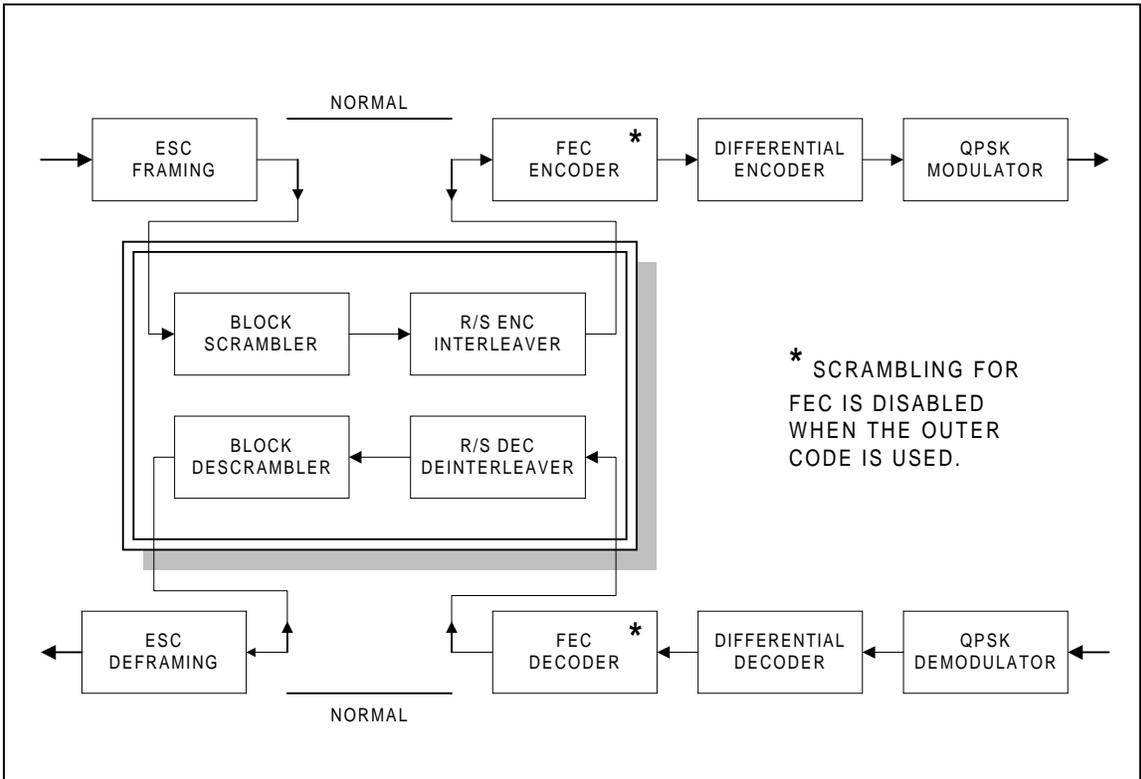


Figure 1. Reed-Solomon Outer Code Implementation

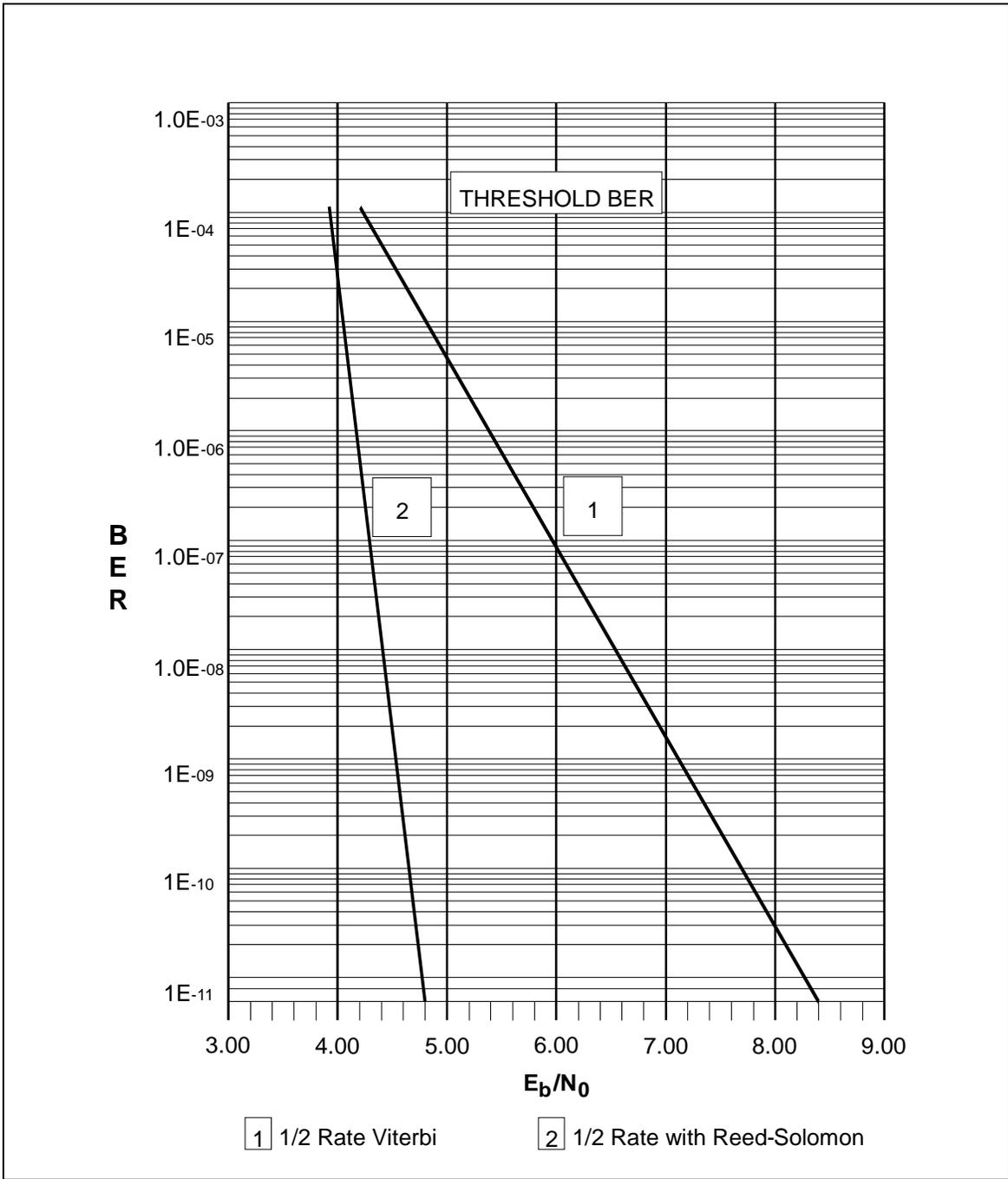


Figure 2. Concatenated Codes for IBS

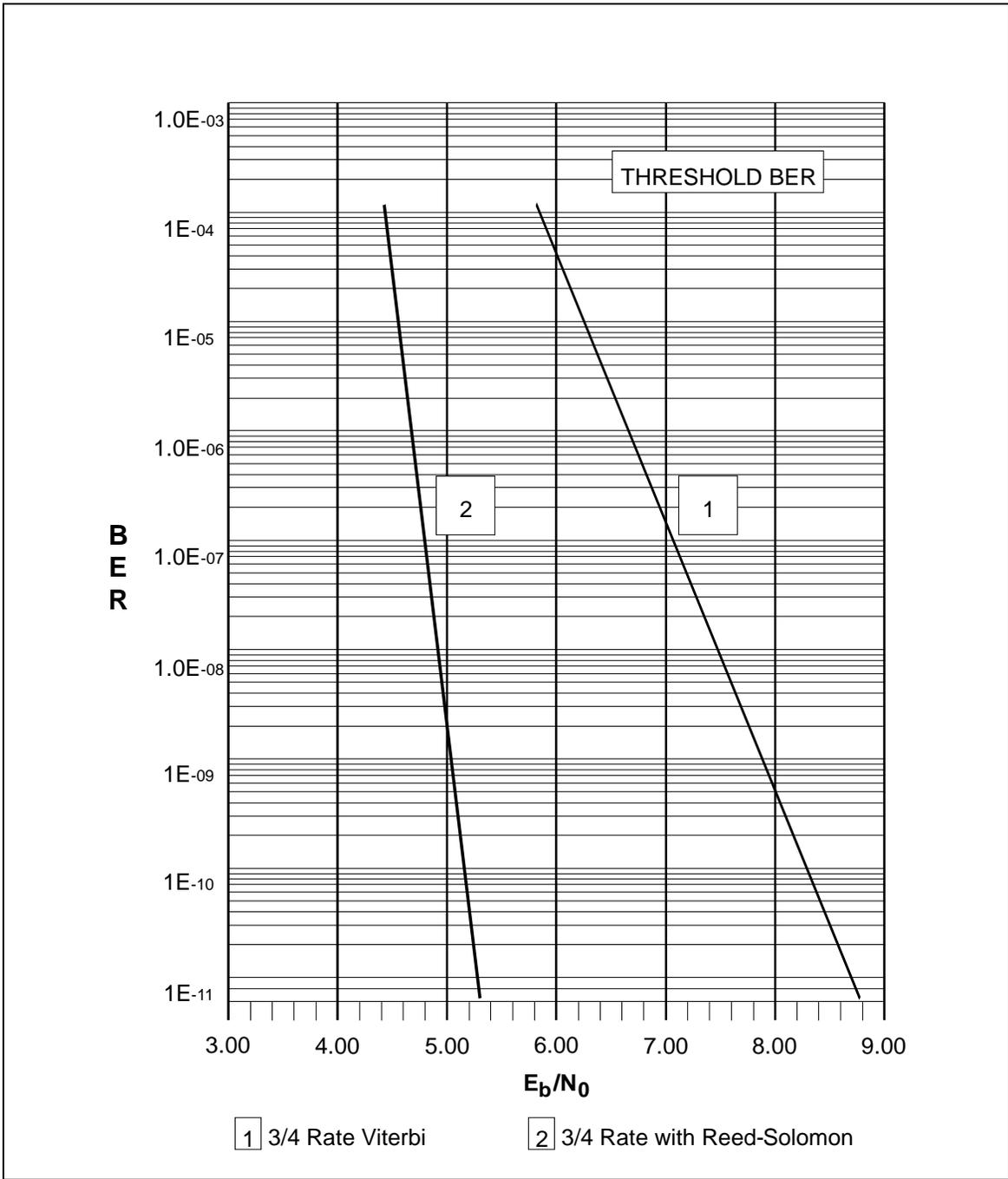


Figure 3. Concatenated Codes for IDR

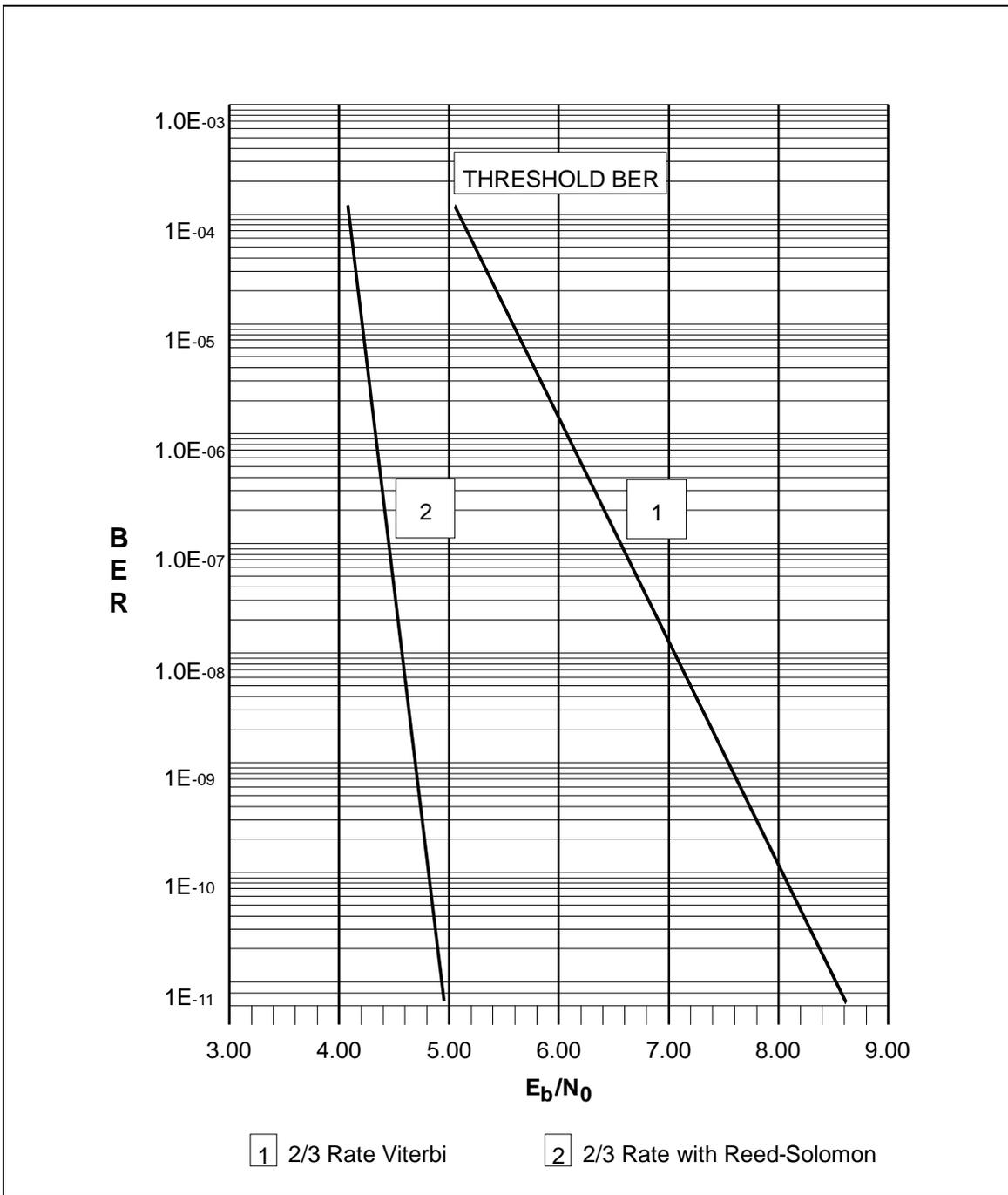


Figure 4. Concatenated Codes for HDTV



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