IEEE 802.3bp RTPGE FEC Contribution

VITESSE

Making next-generation networks a reality.

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Supporters

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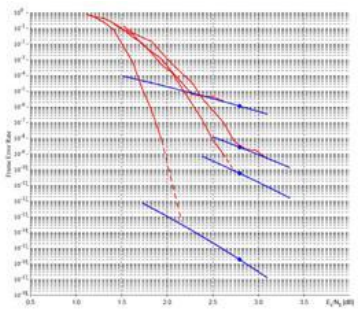
- **Definitions**
- **Assumptions**
- **Code Candidates**
- **Code Selection based on assumptions**
- **Performance**
  - Coding Gain
  - Burst Error Performance
- **Flexibility of Selection**
- **Summary**

Definitions

- **Concatenated Codes**
  - Product of two subcodes, where overall rate is a product of the independent rates and the code size is also a product of the constituent codes.
- **LDPC**
  - low density parity check codes, invented by Gallagher in 1960's, a class of soft iterative decodable codes
- **Waterfall and Error Floor Regions** of the BER performance curves
  - Red area is the waterfall region, (low SNR)
  - Blue lines are the error floor region, (high SNR)



- **Puncturing and shortening** – techniques applied to a code, to produce a new codeword set that is smaller and custom tuned to an application.

Assumptions

- **Assumptions**
  - An energy efficient modulation scheme is chosen such under our channel model agreements a target FEC coding gain on the order of ~5dB is required to meet our BER objectives.
  - A high rate code is desired, overhead <10%, implying code rates >90%
  - Burst Error correcting code would be desirable
  - Low latency is desired
  - Good performance in the “error floor” region
    - Wireline-like performance vs Wireless-like performance
  - Allows puncturing or shortening to adjust the code to our application

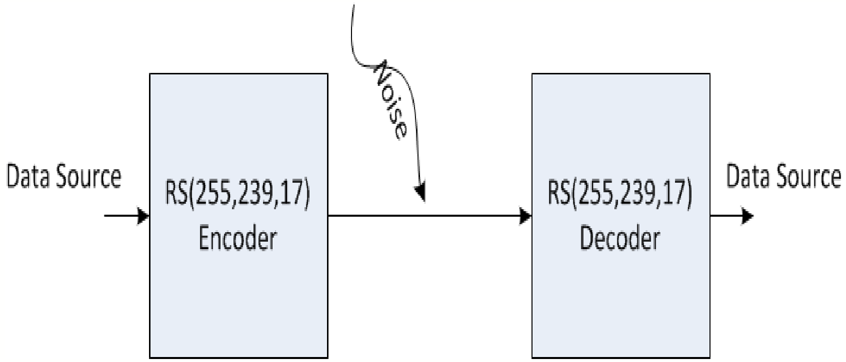
Code Candidates

- **Based on the assumptions of High Rate Codes, 90%**

Code Type	High Rate Codes, >90%	Candidate Code?
Classic Algebraic Codes	Selected members of the BCH, Reed Solomon, family of codes achieve high rates and low error floors	Yes
LDPC	A few, specified in 802.15.3c for example, but poor performance in the error floor region	No
Concatenated Codes, TPC	Tough to find at 90% code rate unless component codes are very large, then latency is a concern. Accumulator codes might meet the code rate requirements but tend to perform poorly in the error floor region.	No
Turbo Codes	Not high enough rate, poor error floor performance	No

* If code rate is relaxed (>80%) then this opens the door for LDPC, Concatenated Codes

Code Selection

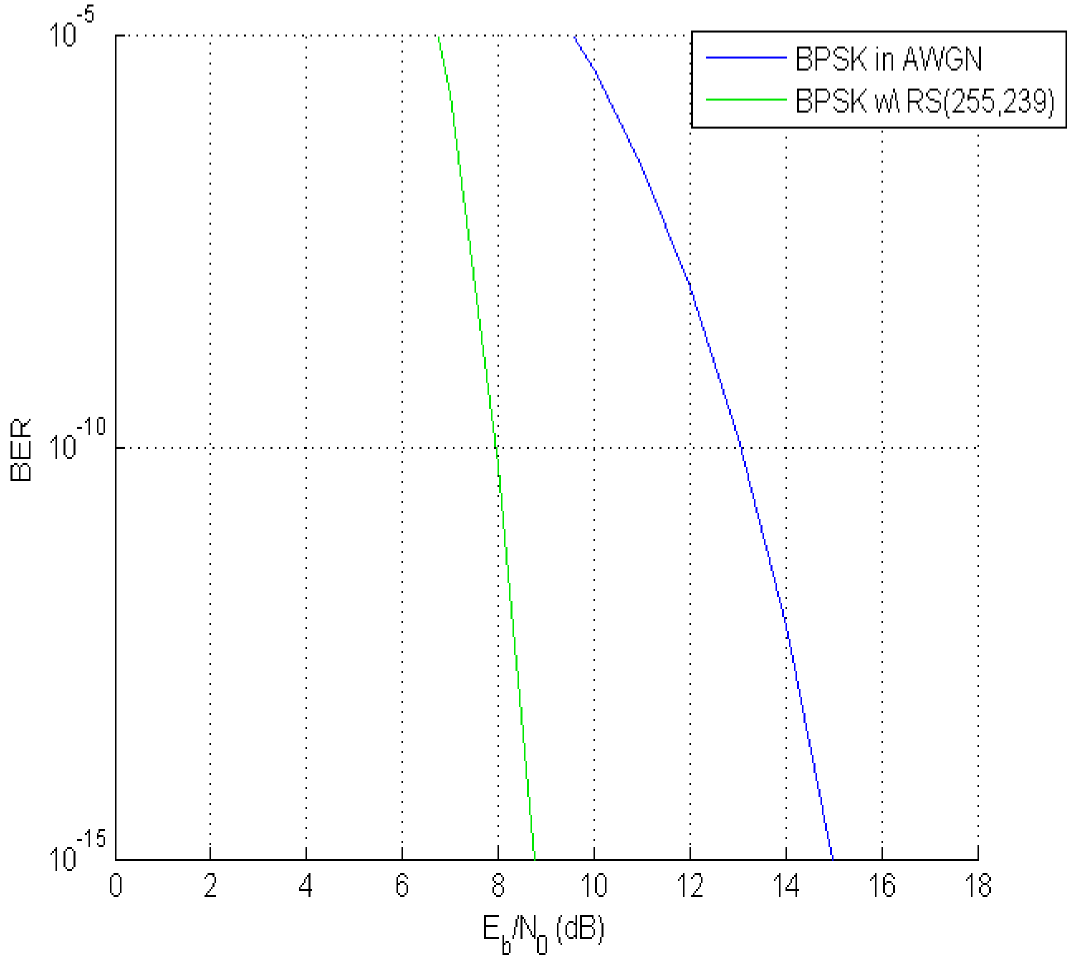


- **RS (255,239,17)**
  - Reed Solomon non binary cyclic code
  - S=8 size of symbol
  - N=255 symbols per codeword
  - K=239 information symbols per codeword
  - D=17 minimum hamming distance between any two codewords
  - Distance = 17, implies t=8 error correcting capability
  - Particularly useful for burst error correction
  - Flexibility, can be easily shortened (some performance penalty will result)

Erasure decoding Performance

- **The Erasure decoding performance of a RS code is:**
  - ❑ $R = d_{min} - 1 = n - k$ in this case 16, twice as many symbols can be corrected if we know where the symbol errors are.
  - ❑ Simultaneous Erasure capability and error correction is related by:
    - ❑ $2a + b < d_{min} < n-k$
      - ❑ Where a = unknown error locations
      - ❑ Where b = known erasures

Performance



- Assume Hard Decoding
- Coding Gain*
  - ~5dB at BER= 10^{-10}
  - ~6.2dB at BER= 10^{-15}

- * Not the Net effective coding gain

Flexibility of Code Selection

- **Flexibility of Selection**
  - Shortening, puncturing (size adaptability)
    - Example DVB standard uses a RS(204,188), a shortened code RS(255,239)
  - Improved burst protection through multi block interleaving is possible, at the expense of decoding latency
  - Very good erasure performance
  - Works with most modulation schemes

Summary

- RS(255,239) has been an industry work horse code for good reasons
  - Particularly in wireline, optical where low errors floors are desirable
    - G.709, DVB standards
- An overhead of 6.3% redundancy, achieves ~5dB coding gain at BER=10^{-10}
  - (theoretical performance in AWGN)
- Excellent Burst Error Correction capability
  - Important in an environment known to have impulse noise sources
- Flexible
  - Code can be shortened to match to framing protocols and improve latency
  - Good erasure performance
- Low latency

Next Steps

- Validate the assumptions
- After a first round of looking at modulation and coding, it would be nice to have targets for coding gain, latency, burst correction criteria, and overhead, to iterate to a more refined FEC selection.