Analysis of Different Error Correction Codes

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Topics Covered

- Existing Literature
- Introduction
- Error Detection Codes
- Error Correction Codes
- Applications
- Results
- Conclusion
- Project Demonstration

Existing Literature

- LDPC code construction with flexible hardware implementation.
  - Explains LDPC for hardware implementation
- Improved decoding of Reed-Solomon and algebraic-geometric codes
  - Describes Reed-Solomon codes decoding
- A novel ARQ scheme applied to wireless communication.
  - shows how ARQ is used for wireless transmission
- The Development of Turbo and LDPC Codes for Deep-Space Applications.
  - Explains Turbo codes and LDPC codes for high end applications
- These research papers explain ECC in specific situations.
- This makes it hard to compare these codes on more general form.

Introduction

- When data is transmitted over a wired or wireless links, errors might be introduced because of channel noise.
- Error detection codes
  - used to check if errors occurred during transmission.
- Error correction codes
  - help the receiver to recover the corrupt data even when there is no back channel.

Error Detection Codes

1. Parity Bits
2. Repetition Code
3. Checksum
4. Cyclic Redundancy Checks

Parity Bits

- Parity Bits is one of the most simple error detection codes.
- In this example, a parity bit is added to a 7 bit binary code, which results into 8 bit binary code.

7 bit code	Even Parity		Odd Parity	
	Parity Bit	8 bit code	Parity Bit	8 bit code
1011010	0	10110100	1	10110101
1010010	1	10100101	0	10100100
0100101	1	01001011	0	01001010
1111000	0	11110000	1	11110001
0011100	1	00111001	0	00111000

Repetition Code

- In (4,1) repetition code
  - Blocks are sent 4 times. For example in this case, 011 is sent like 011 011 011 011.
  - If any of the block is different from the other, then there is an error.
  - At the receiver, we can decode the signal by majority vote.
- Advantage
  - This is a simple error detection code.
- Disadvantage
  - This method is very inefficient because data is sent multiple times.
  - If a bit flip is in the same place for all the blocks. Then this method would not be able to detect the error

Checksum (STEPS)

1. We compute the checksum of data using a checksum function.
2. This checksum is sent along with the data.
3. The receiver separates the data and the checksum.
4. Then it uses the same checksum function to determine the checksum.
5. This new checksum is compared to the checksum received.
6. If they are different, then the data received is corrupt.

Cyclic Redundancy Checks (STEPS)

1. We use a generator polynomial to perform long division on data.
2. In this method, the generator polynomial is the divisor, the data is dividend and remainder is used to find errors.
3. This remainder is sent with the data.
4. Receiver uses same method to find the remainder.
5. This new remainder is compared with remainder received to determine if there is an error.

Using Cryptographic Hash Functions

- We can use same cryptographic hash function at sender and receiver to find errors.
- Cryptographic hash value of a data is unique.
- Chances of collision are very less.

Error Correction (using ARQ)
3 types

1. Stop and Wait
2. Go Back N
3. Selective Repeat

Error Correction Code (FEC)

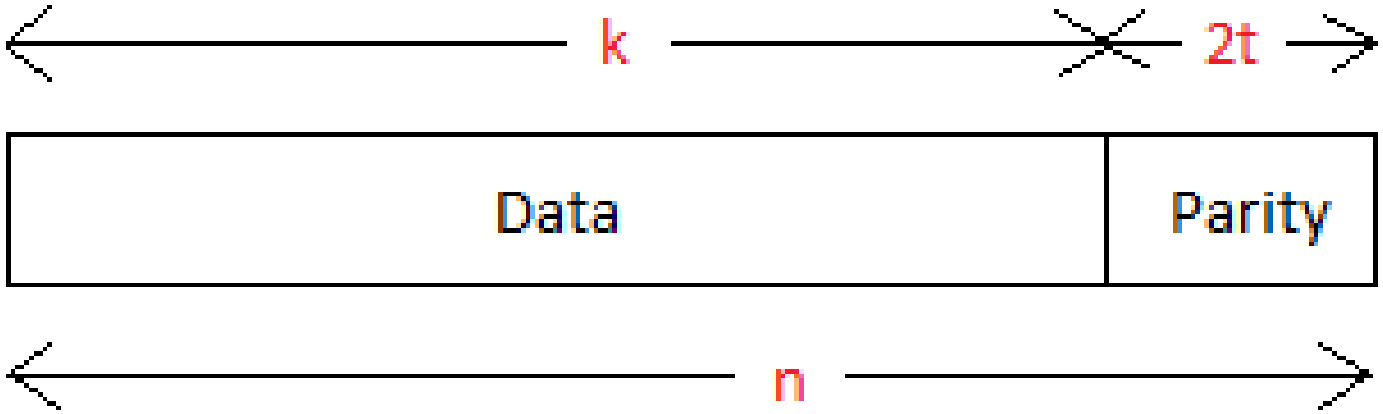
1. Reed-Solomon
2. Low Density Parity Check Code (LDPC Code)
3. Turbo Code
4. BCH Codes

Reed-Solomon code (encoder and decoder)

1. Encoder - Add redundant data to the data message
2. This message then sent through the communication channel.
3. The receiver then decodes the data by using Reed-Solomon decoder

Reed-Solomon codeword

- Reed-Solomon code word
  - n bits contains
  - k bit of data and
  - 2t bits of parity data
  - Can detect 2t bits of error and correct t bits

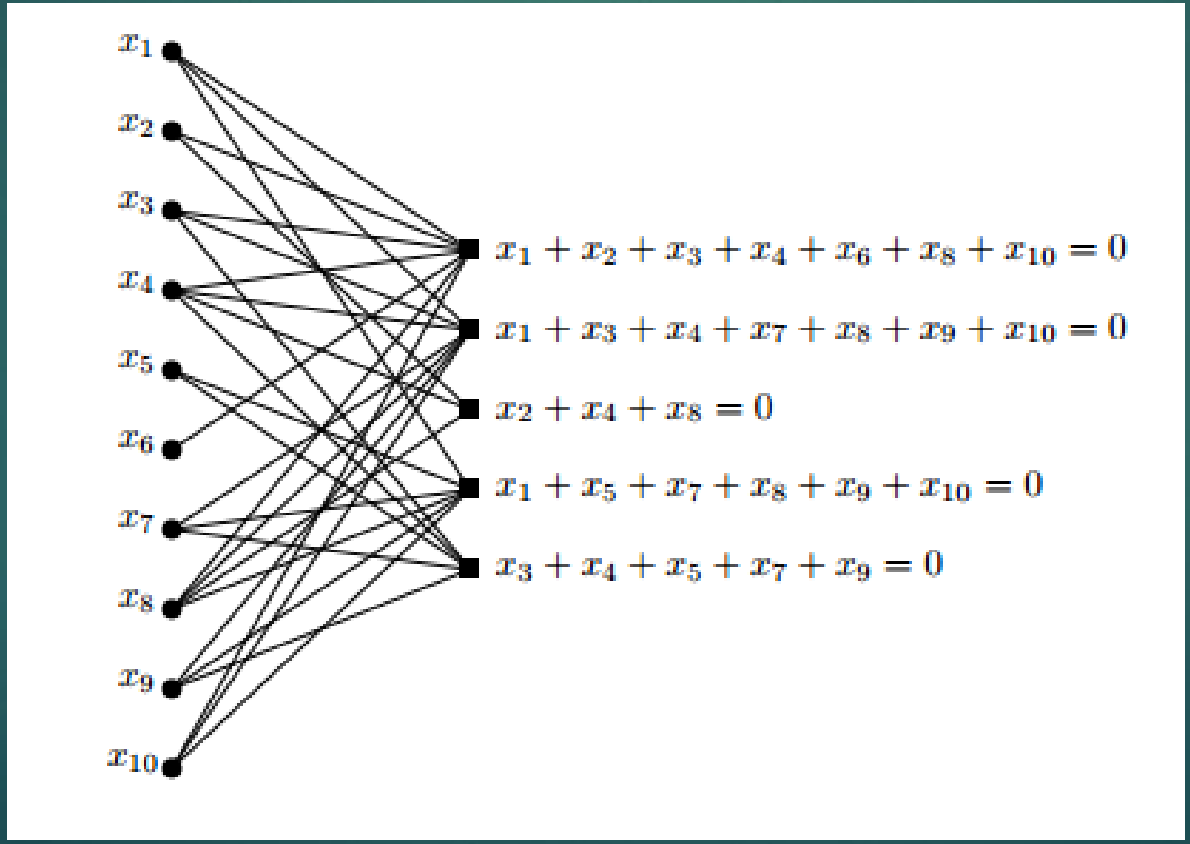


Reed-Solomon Applications

- Advantage
  - Easy to code.
- Applications
  - data storage disks like compact disk and DVD.
  - bar codes
  - space transmissions.
- However, they are being replaced by turbo codes

Low Density Parity Check Code (LDPC Code)

- LDPC codes are made using sparse bipartite graphs.



LDPC (continued…)

- LDPC decoders have iterative algorithms.
- That is, in each iteration
  - message is sent from Message -> Check nodes
  - Check ->Message nodes.

LDPC Applications

- Advantage
  - Encoders and decoders are very fast.
- Applications
  - Applications in space communication.

Turbo Code

- Performance similar to LDPC codes
  - close to Shannon limit
- Currently competing with LDPC codes in high end applications.
- Interleavers are a part of turbo codes
  - Advantage
    - They give them good performance.
  - Disadvantage
    - However, this makes the decoding slow.

Turbo Code applications

- Applications
  - Applications in 3G and 4G mobile.
  - Used for satellite communications.

BCH Codes

- Applications
  - Storage devices like CD, DVD and SSD.
  - used in satellite communication
  - 2 dimensional bar codes.
- Advantage
  - Simple design.
  - control how many symbols can be corrected initially during design

Convolutional Codes

- These codes can work on symbols of any length.
- It doesn't have to be fixed length like block codes.
- Data encoded using convolutional codes can be soft decoded using Viterbi Algorithm.

Convolutional Codes Applications

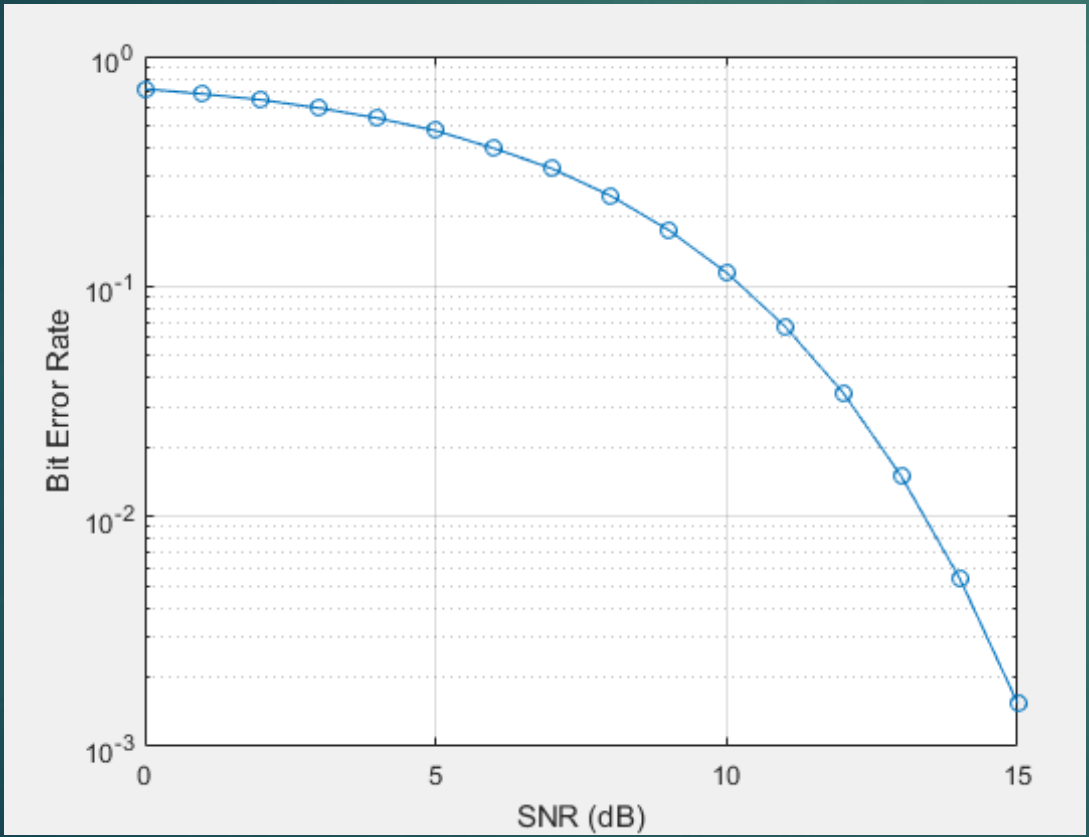
- Application
  - Speech recognition
  - GSM
  - CDMA
  - Satellite communication
  - Bioinformatics

Applications

Wireless Link	ARQ	Reed Solomon	LDPC	Turbo Code	BCH Code
Radio(2 way)	Yes	No	No	No	No
Satellite TV	No	Yes	Yes	Yes	Yes
Bluetooth	Yes	No	No	No	No
CDMA, GSM	Yes	Yes	Yes	Yes	Yes
GPRS, 3G, 4G	No	Yes	Yes	Yes	Yes
Satellite Communication	No	Yes	Yes	Yes	Yes
Deep space communication	No	Yes	Yes	Yes	Yes

Results (Reed Solomon Code)

- Calculate BER for different values of SNR

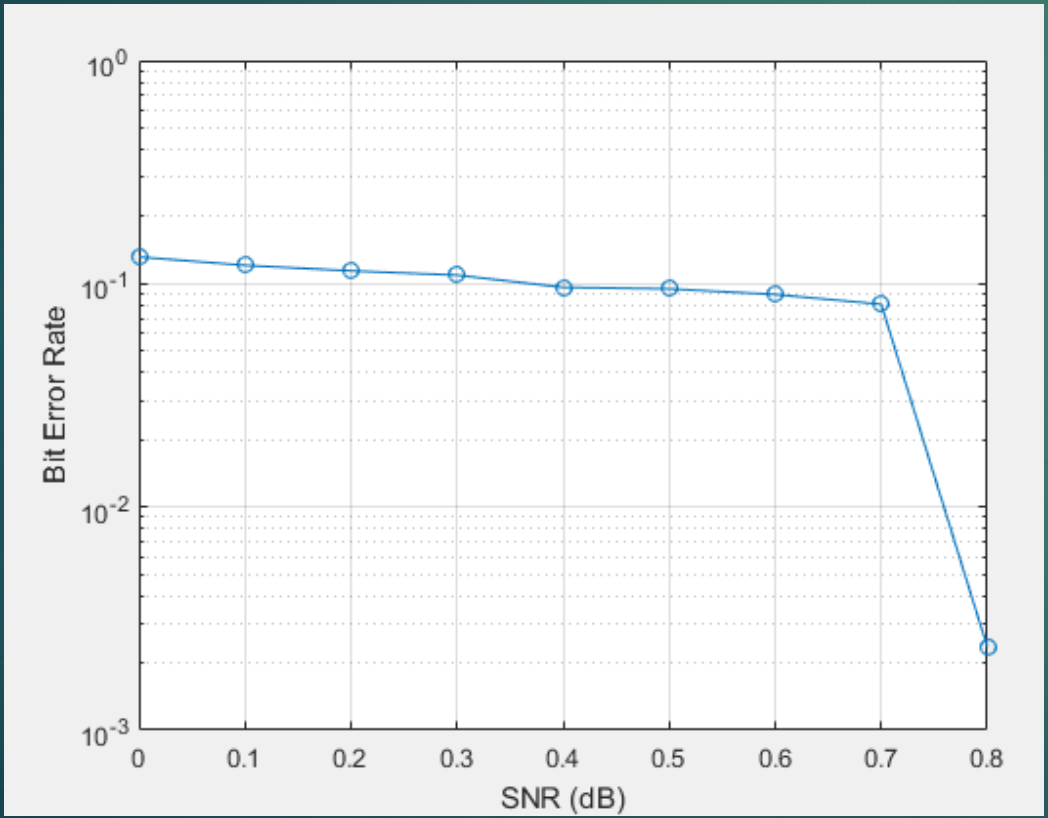


Command Window

```
BER = 0.108605
Total Errors = 130
Total Bits = 1197
Trial>>
```

Results (LDPC)

- Calculate BER for different values of SNR

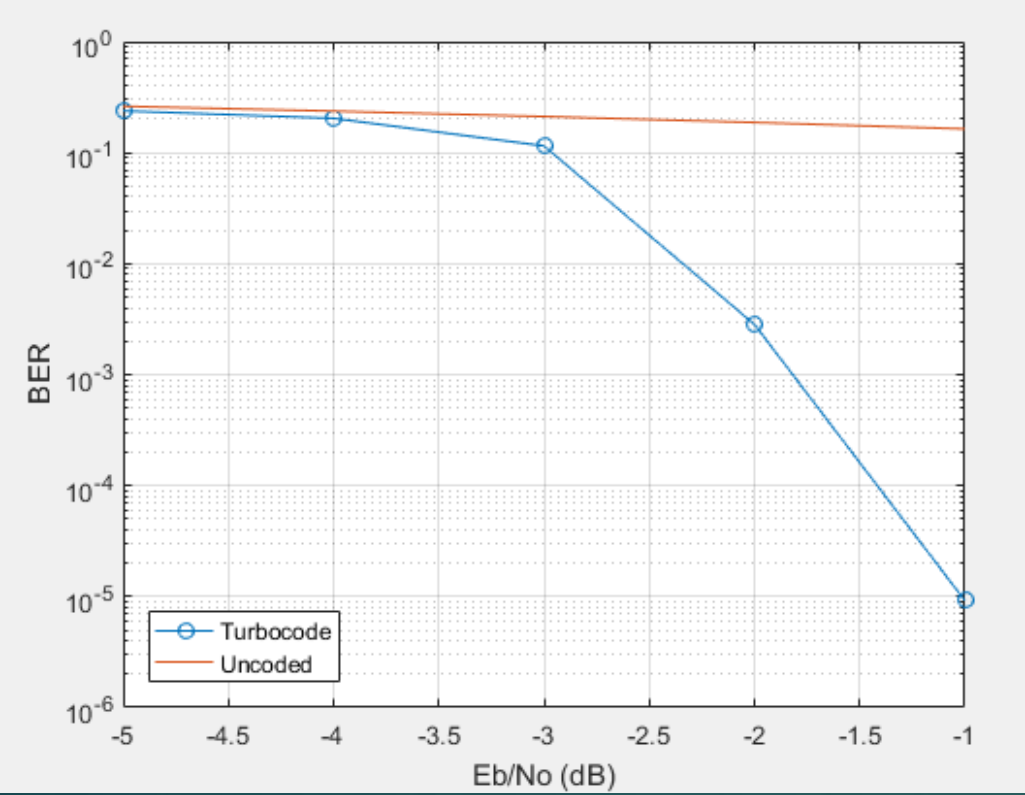


Command Window

```
BER = 0.000473
Total Errors = 230
Total Bits = 485997
Trial>>
```

Results (Turbo Code)

- BER vs Eb/No for Turbo code and un-coded signal

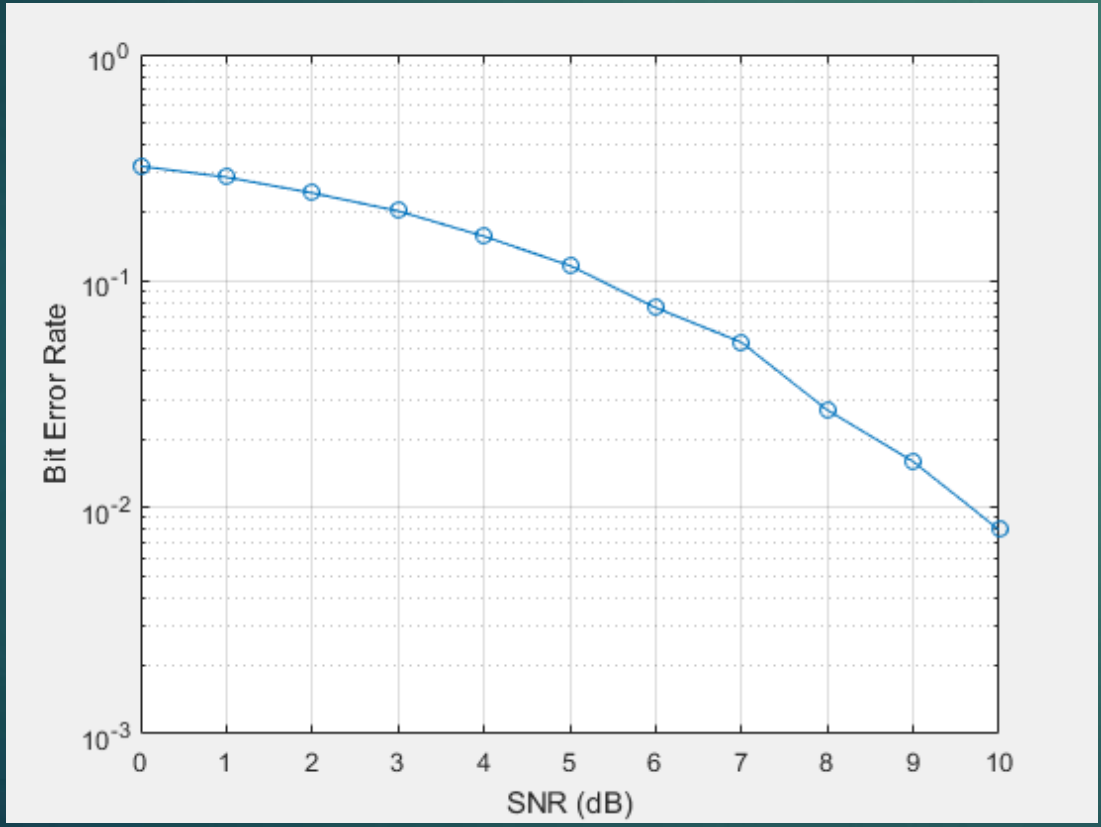


Command Window

```
BER = 0.005001
Total Errors = 96
Total Bits = 19197
Trial>>
```

Results (BCH Code)

- Calculate BER for different values of SNR

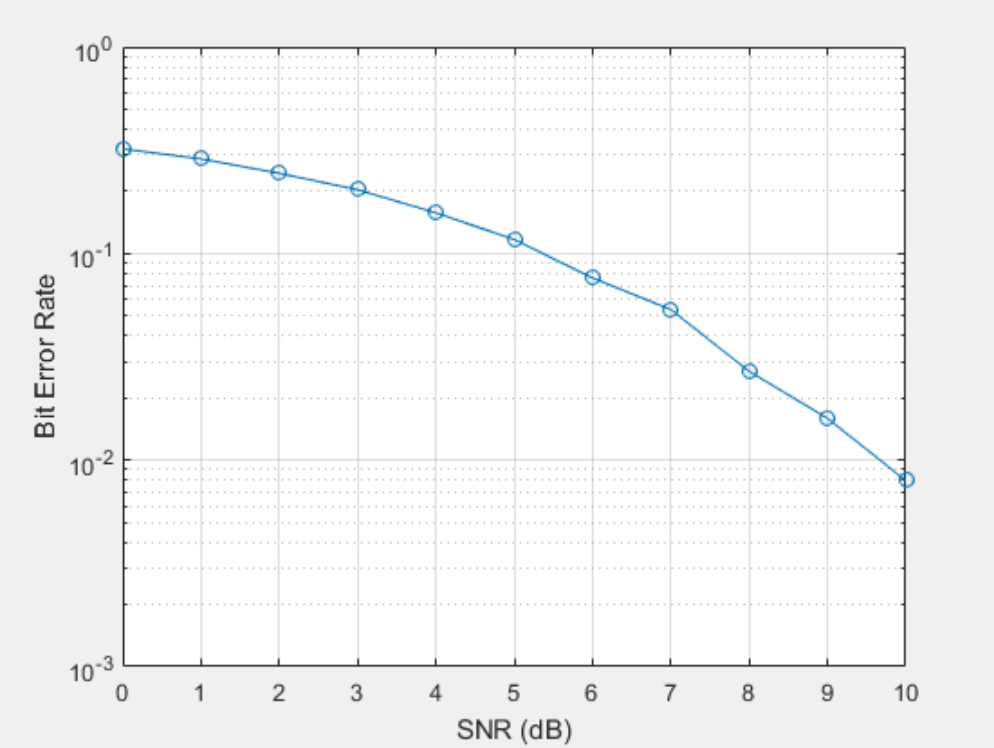


Command Window

```
BER = 0.504188
Total Errors = 301
Total Bits = 597
Trial>>
```

Results (Convolutional Code)

- BER vs Eb/No for Turbo code and un-coded signal



Command Window

```
BER = 0.504188
Total Errors = 301
Total Bits = 597
Trial>>
```

Conclusion

- Unreasonable to conclude that a particular Error Correcting code would work optimally for all applications.
- The use of an ECC depends on factors like
  - Latency
  - channel noise
  - type of errors,
  - Simplicity
  - Performance
  - hardware involved.

Conclusion (continued…)

- ARQ is widely used in network protocols for reliable communication.
- Reed-Solomon code and BCH Code are widely used for storage devices like CD ROM, DVD and SSD.
- BCH codes are used in 2-D bar codes.
- LDPC code, Turbo codes and Reed-Solomon code are used for satellite and deep space communication.
- Turbo codes are competing with LDPC codes for high end applications.

Project Demonstration !!!

Thanks for watching !!!