A Quasi-Cyclic LDPC Code for NavIC L1 Band Signal

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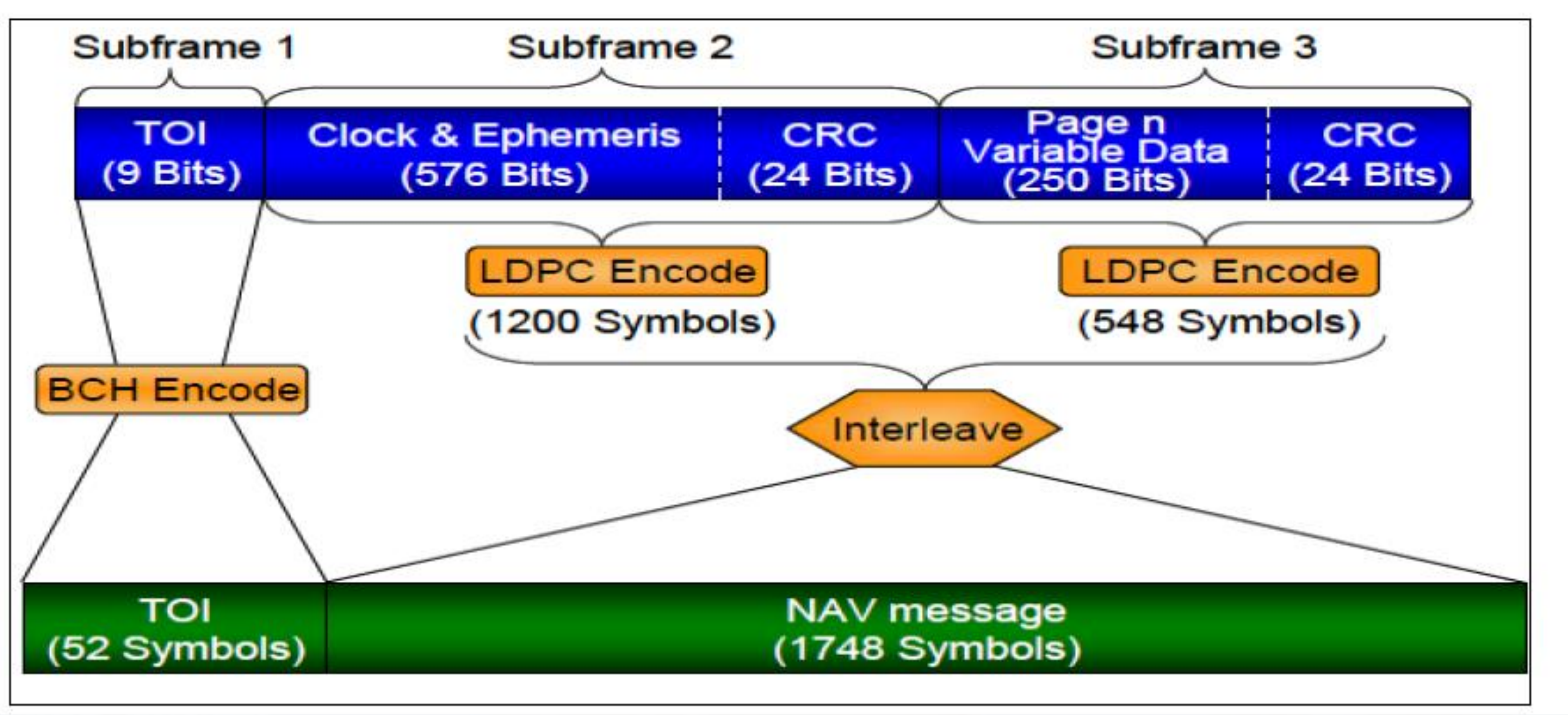
Abstract

Low-density parity-check (LDPC) codes [1] are a class of modern channel coding. Because of the advantages of approaching the Shannon capacity and the iterative decoding algorithms with lower complexity, LDPC codes have been attracting great interests even in the field of satellite navigation systems. In GPS modernization, LDPC code is used in L1C signal to enhance the receivers' performance in weak signal environments. India is also planning to transmit civilian signal in L1 Band. There are various design approaches of LDPC codes being considered. Quasi-Cyclic LDPC code is found to be an ideal candidate for smaller frame length satellite navigation systems [2]. Recently Quasi-cyclic (QC) LDPC codes is also adapted in 5G communications, it is chosen as the standard codes for 5G enhanced mobile broadband (eMBB) data channel [3].

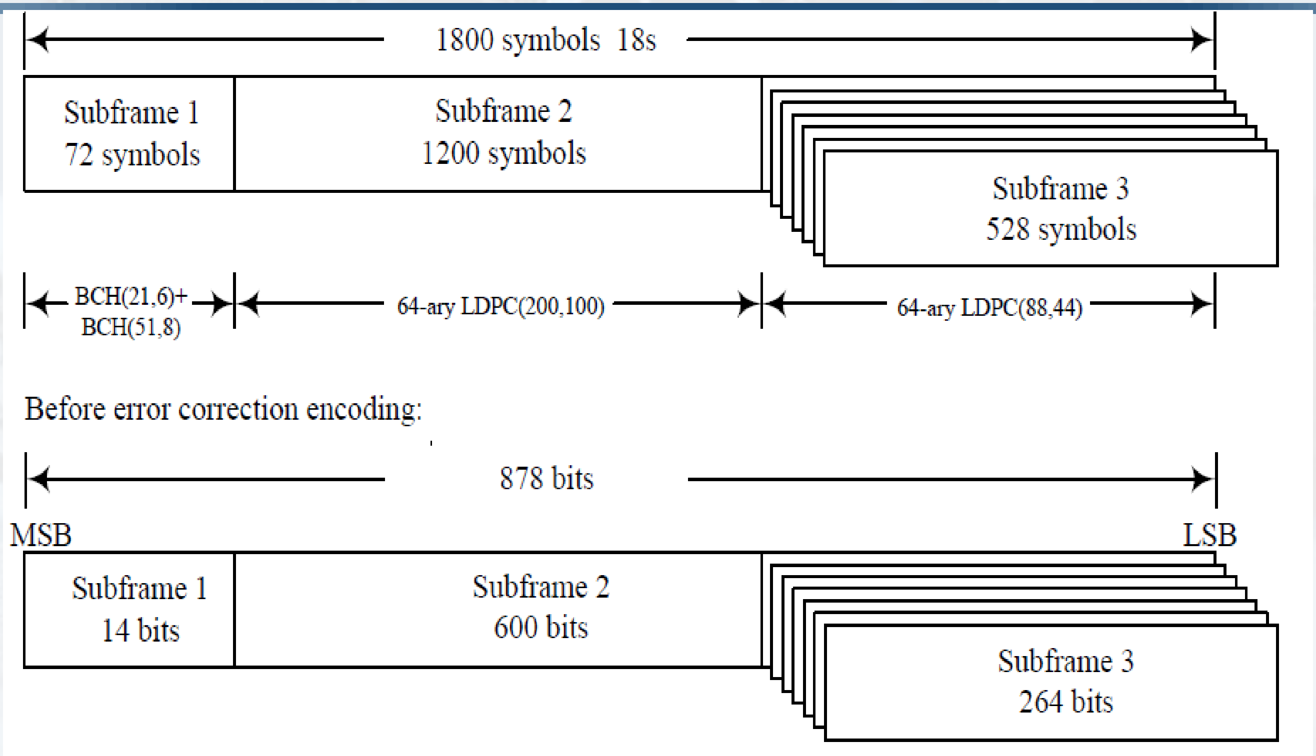
In this presentation we have proposes a constructing algorithm for Quasi-Cyclic LDPC code which is suitable for proposed NavIC L1 Band signal, it avoids the existence of short cycle with the length of 4 in the Tanner graph from the beginning, by limiting the cross-correlation values of sparse sequences. Since the parity-check matrix of a QC-LDPC code consists of circulant permutation matrices or the zero matrix, the required memory for storing it can be significantly reduced, as compared with randomly constructed LDPC codes [4]. Using dual-diagonal structure, the parity-check matrix can be directly used to encode thus there is no need to calculate generator matrix.

GPS L1C



- Different rate-½ irregular LDPC codes are used for the two sub frames.
- The two block lengths of 600 bits and 274 bits respectively. Subframe 2, which is longer, benefits more from the LDPC code, providing the same Subframe error rate at approximately 0.5 lower Eb/N0 than Subframe 3.

BeiDou Navigation Satellite System



B-CNAV1 frame structure

- Non Binary LDPC codes are used for the two sub frames.
- The two block lengths of **64-ary LDPC(200,100)** and **64-ary LDPC(88, 44)** respectively. Each
- Codeword symbol is composed of 6 bits and defined in GF(26) domain with the primitive polynomial of p(x)=1+x+x^6

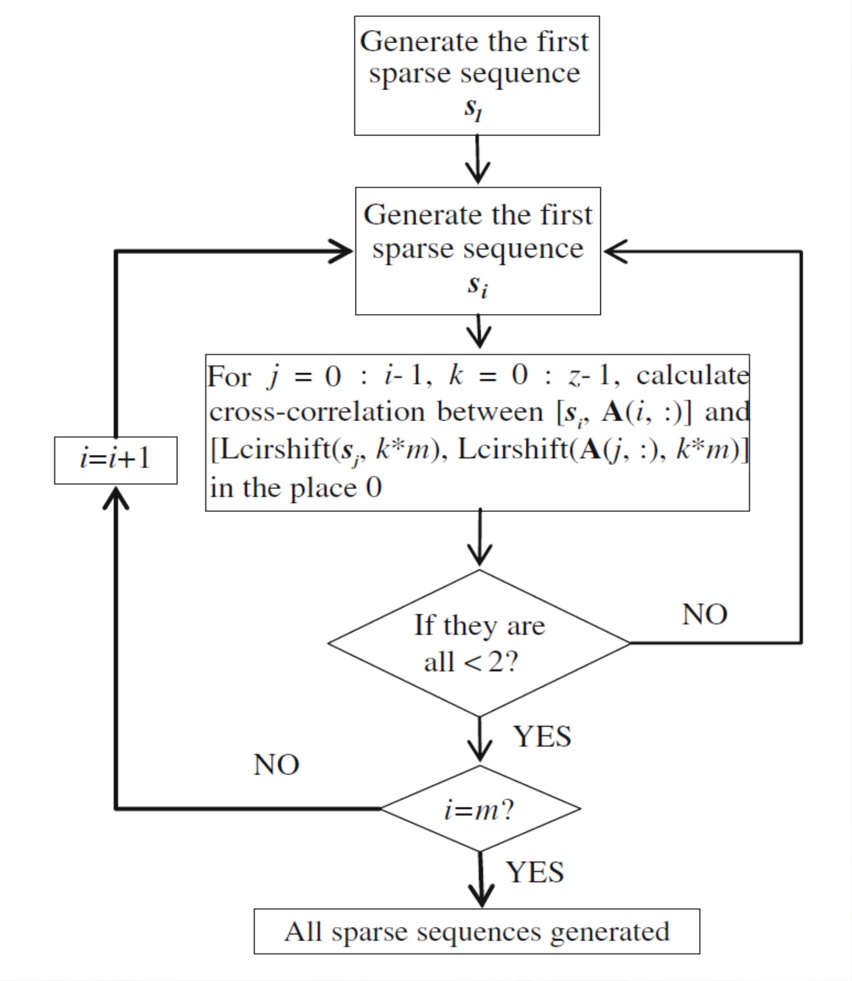
LDPC CODES FOR NavIC L1C

There are various approaches studied and considered for simulation. In all the approaches GPS L1 C signal structure is taken into consideration. A MATLAB based approach is taken all cases. The detailed are listed as below.

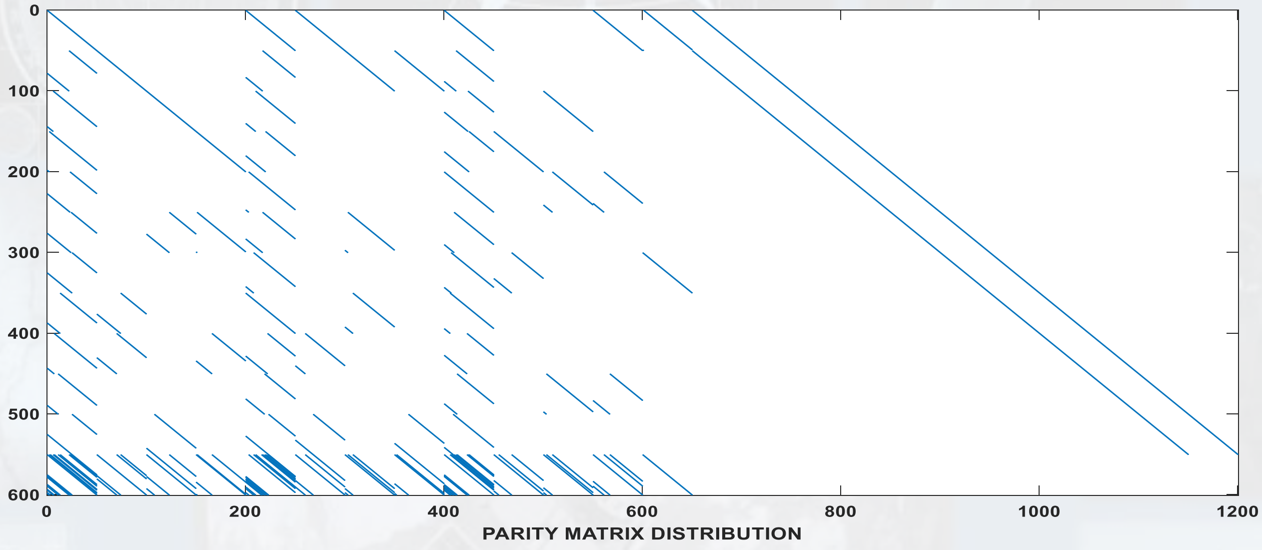
1. Regular Binary Quasi cyclic LDPC code Construction using vandermonde like block matrix.
2. Construction of Non-Binary Quasi-Cyclic LDPC Codes Based on Two Arbitrary Subsets of a Finite Field.
3. Quasi-Cyclic LDPC Code.
4. Construction of Irregular PCM based on V-matrix.

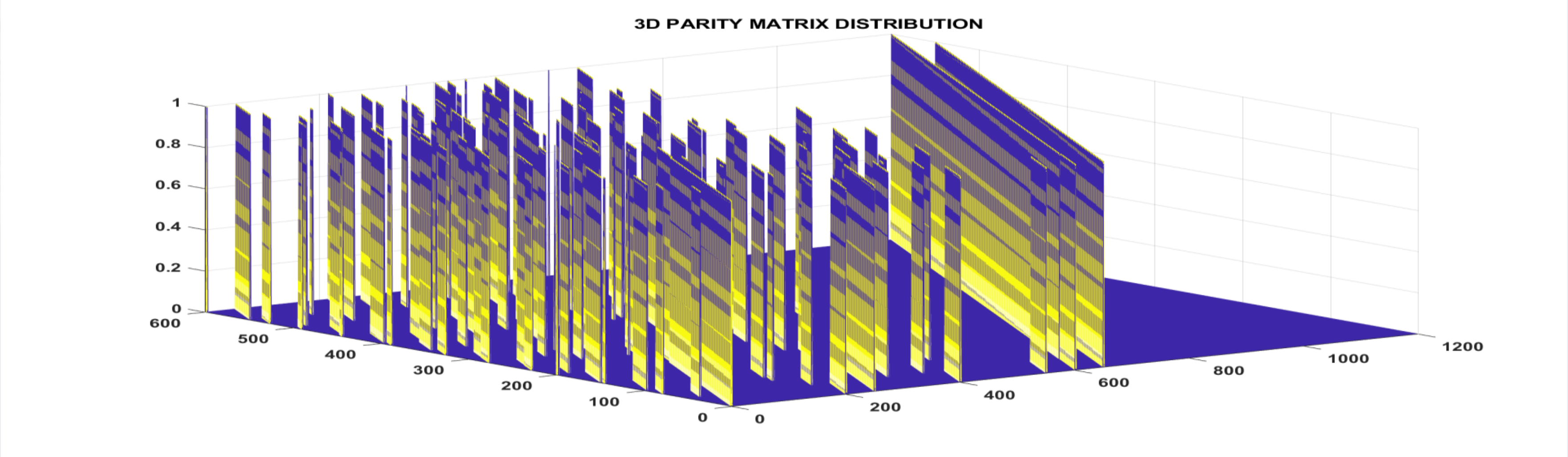
The performance and complexity of Quasi-Cyclic based LDPC Codec is better with respect to other approaches and it is selected for future NavIC L1C signal.

Quasi-Cyclic LDPC Code

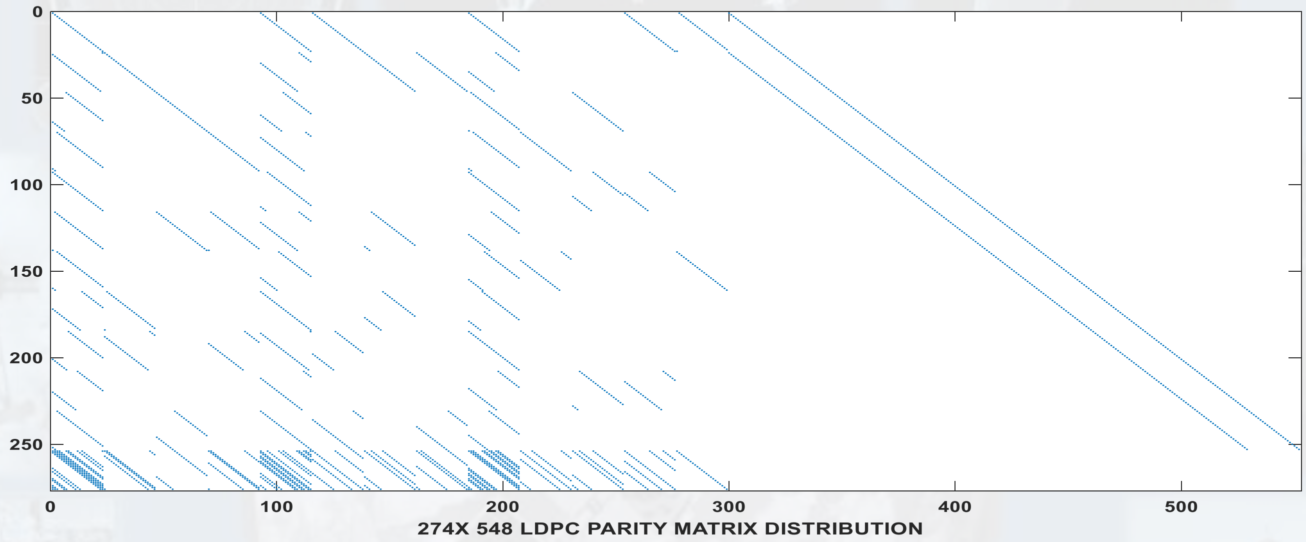


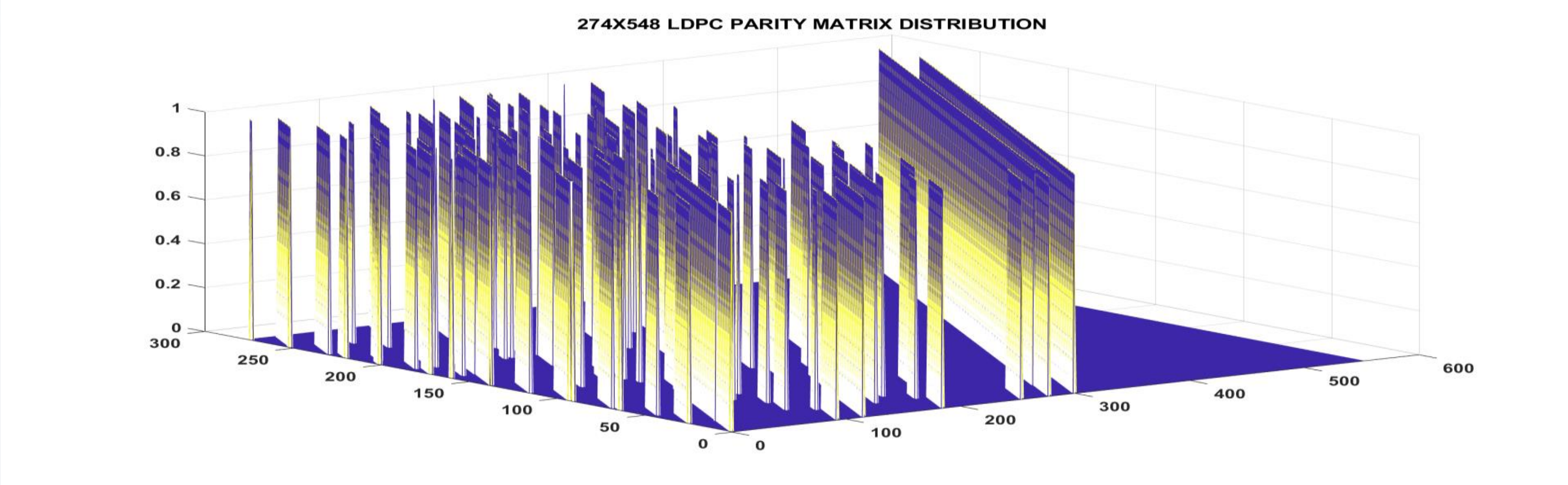
600x1200 LDPC PARITY MATRIX DISTRIBUTION

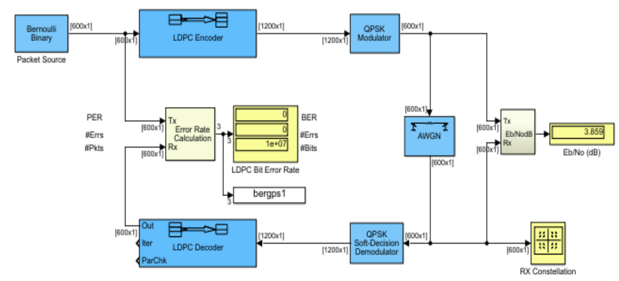




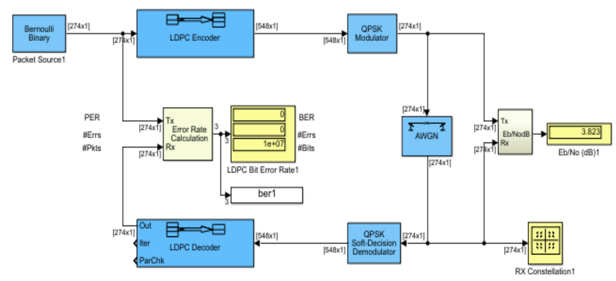
274X548 LDPC PARITY MATRIX DISTRIBUTION



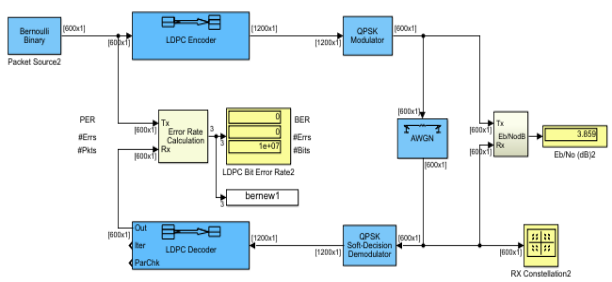




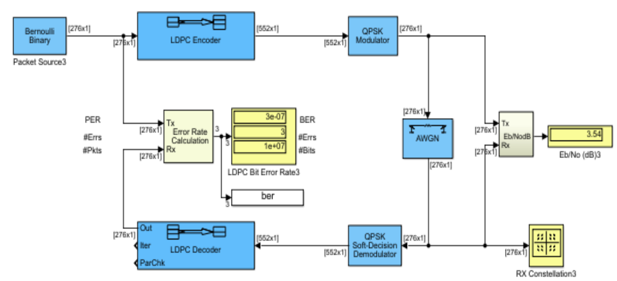
GPS SUBFRAME 2 CODING GAIN SIMULATION



GPS SUBFRAME 3 CODING GAIN SIMULATION

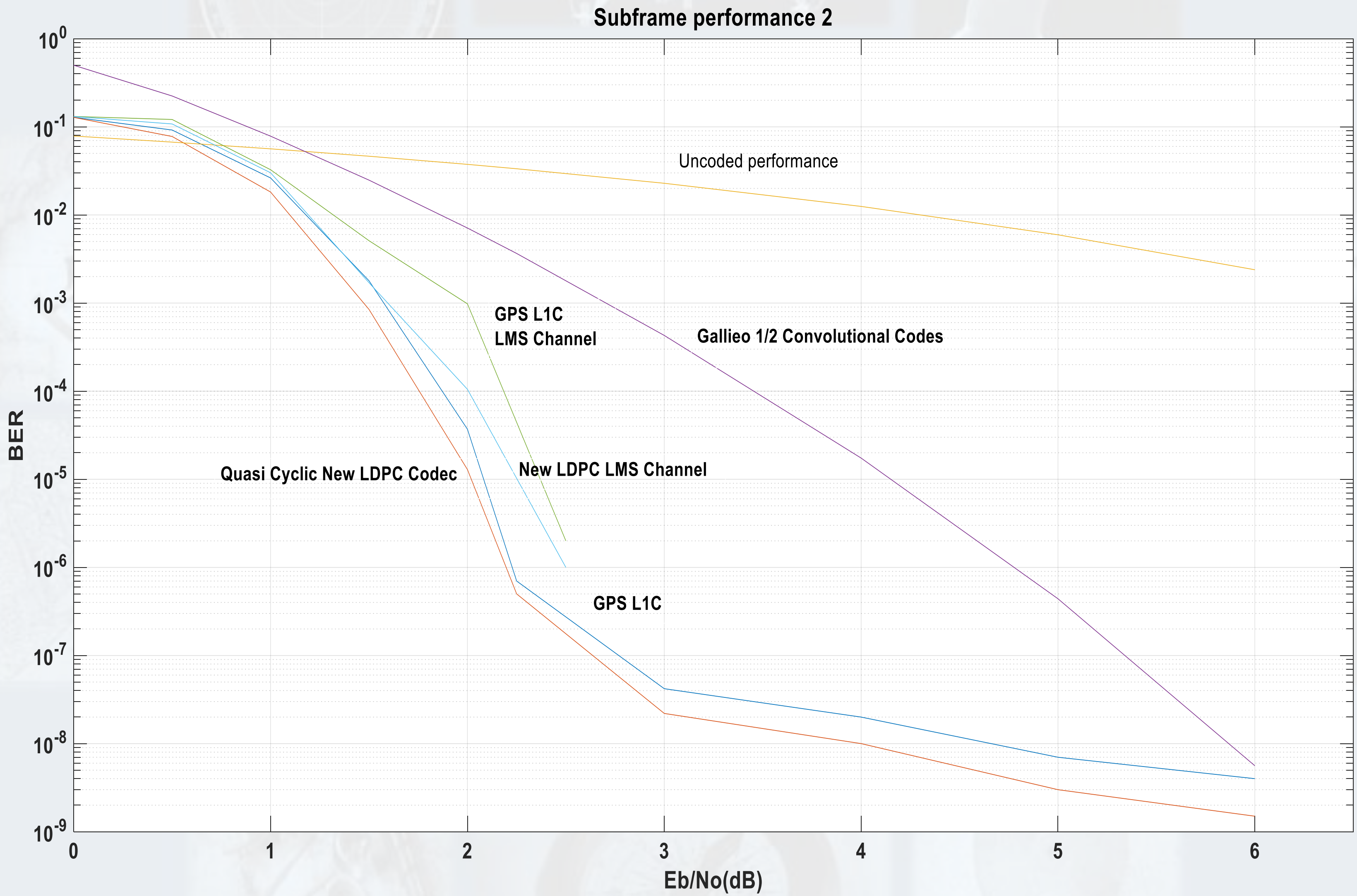


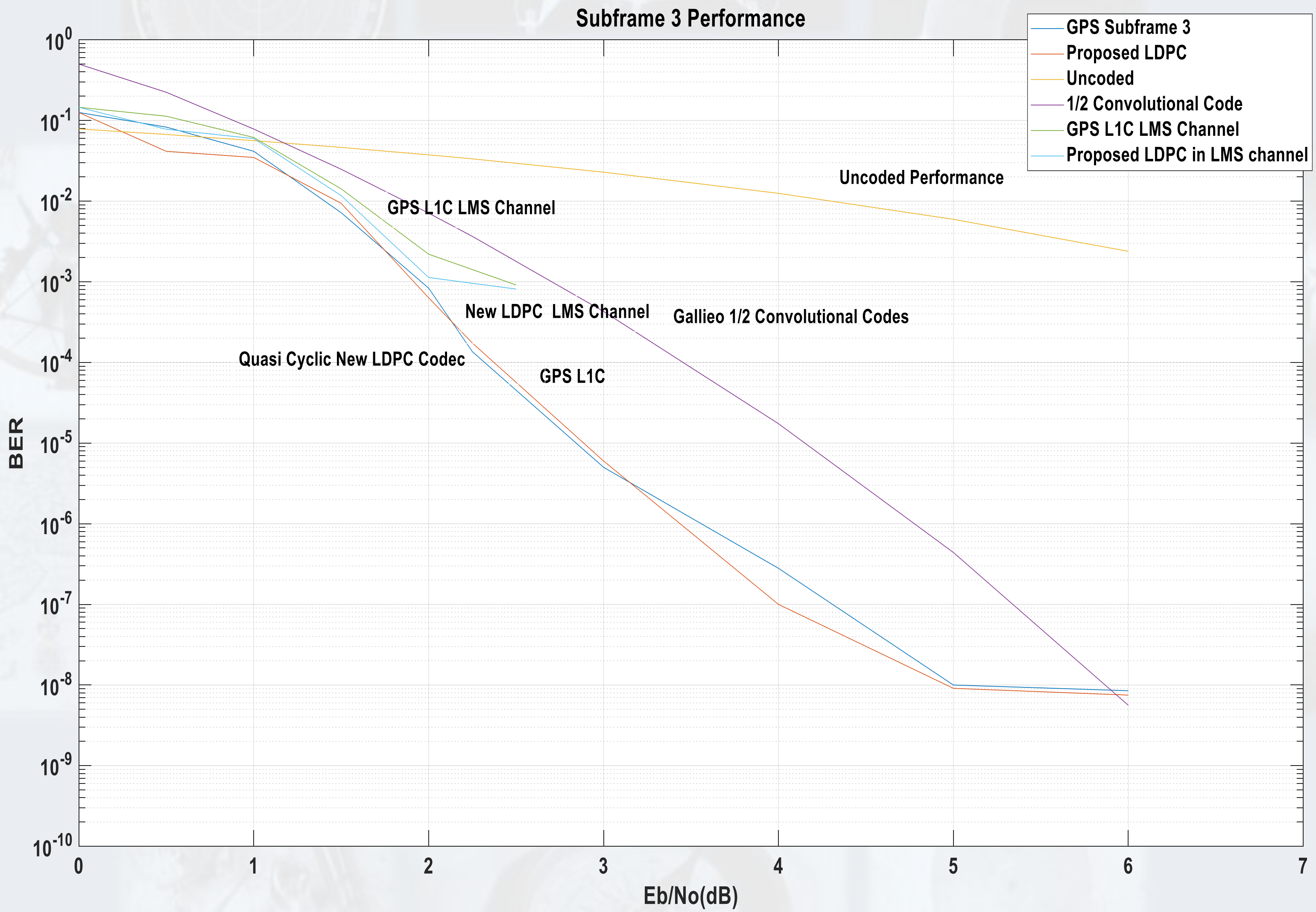
QUASI CYCLIC SUBFRAME 2 CODING GAIN SIMULATION



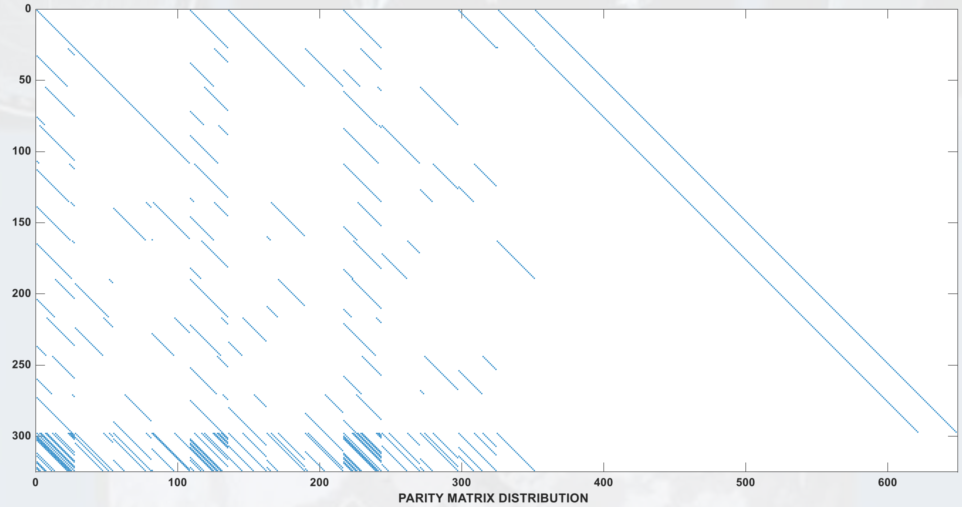
QUASI CYCLIC SUBFRAME 3 CODING GAIN SIMULATION

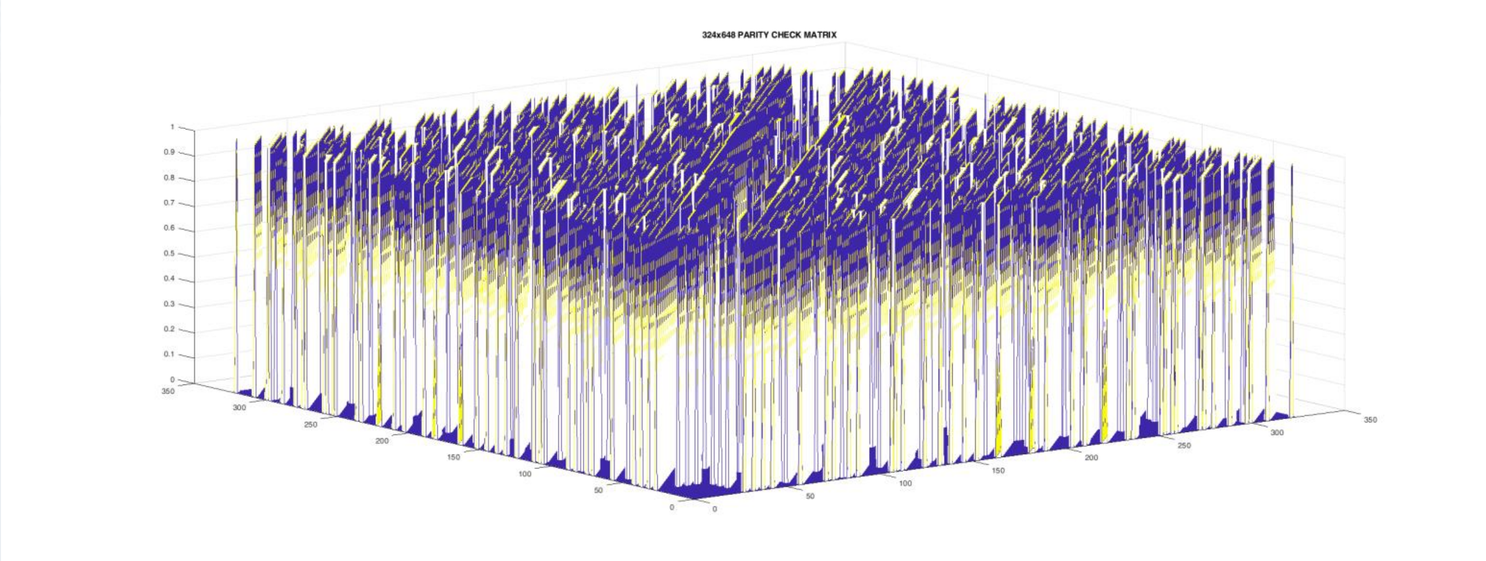
Comparative Simulink simulation of LDPC codec with respect to GPS L1C


Subframe performance 2
BER
Eb/No(dB)
Uncoded performance
GPS L1C
LMS Channel
Gallieo 1/2 Convolutional Codes
Quasi Cyclic New LDPC Codec
New LDPC LMS Channel
GPS L1C
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
10^-8
10^-9
0
1
2
3
4
5
6

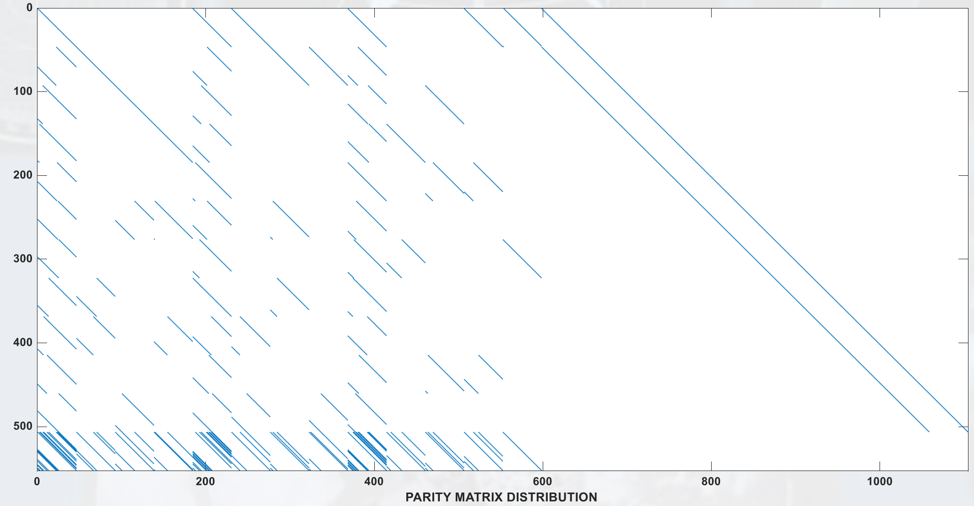

Subframe 3 Performance
GPS Subframe 3
Proposed LDPC
Uncoded
1/2 Convolutional Code
GPS L1C LMS Channel
Proposed LDPC in LMS channel
Uncoded Performance
GPS L1C LMS Channel
New LDPC LMS Channel
Gallieo 1/2 Convolutional Codes
Quasi Cyclic New LDPC Codec
GPS L1C
BER
Eb/No(dB)
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
10^-8
10^-9
10^-10
0
1
2
3
4
5
6
7

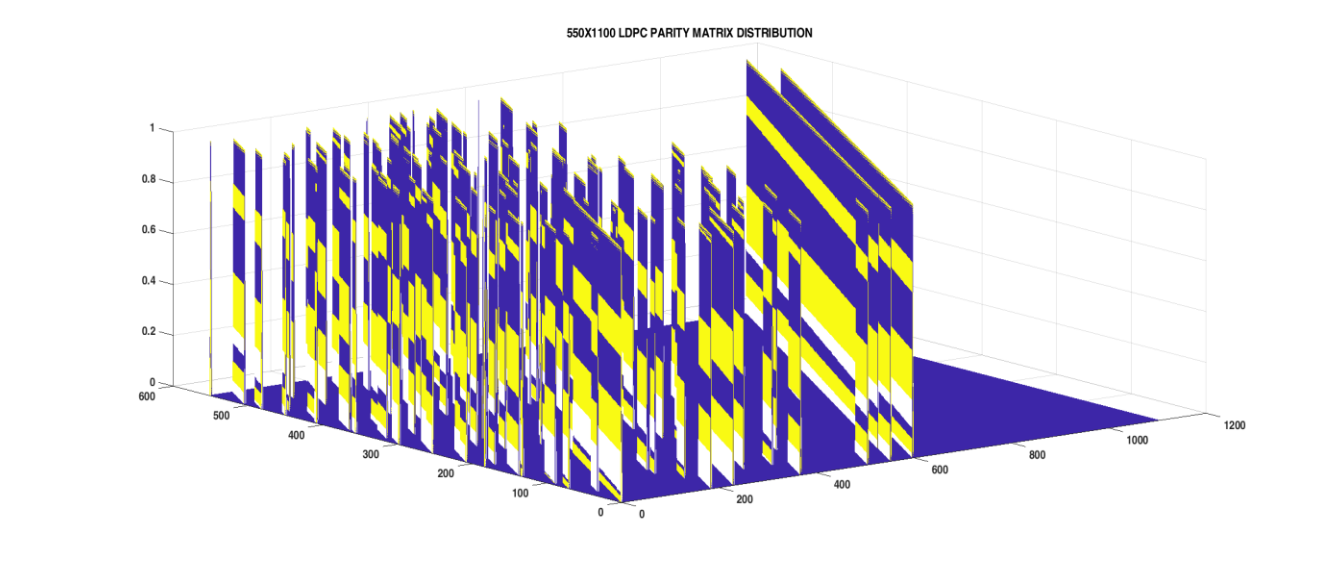
324X648 LDPC PARITY MATRIX DISTRIBUTION

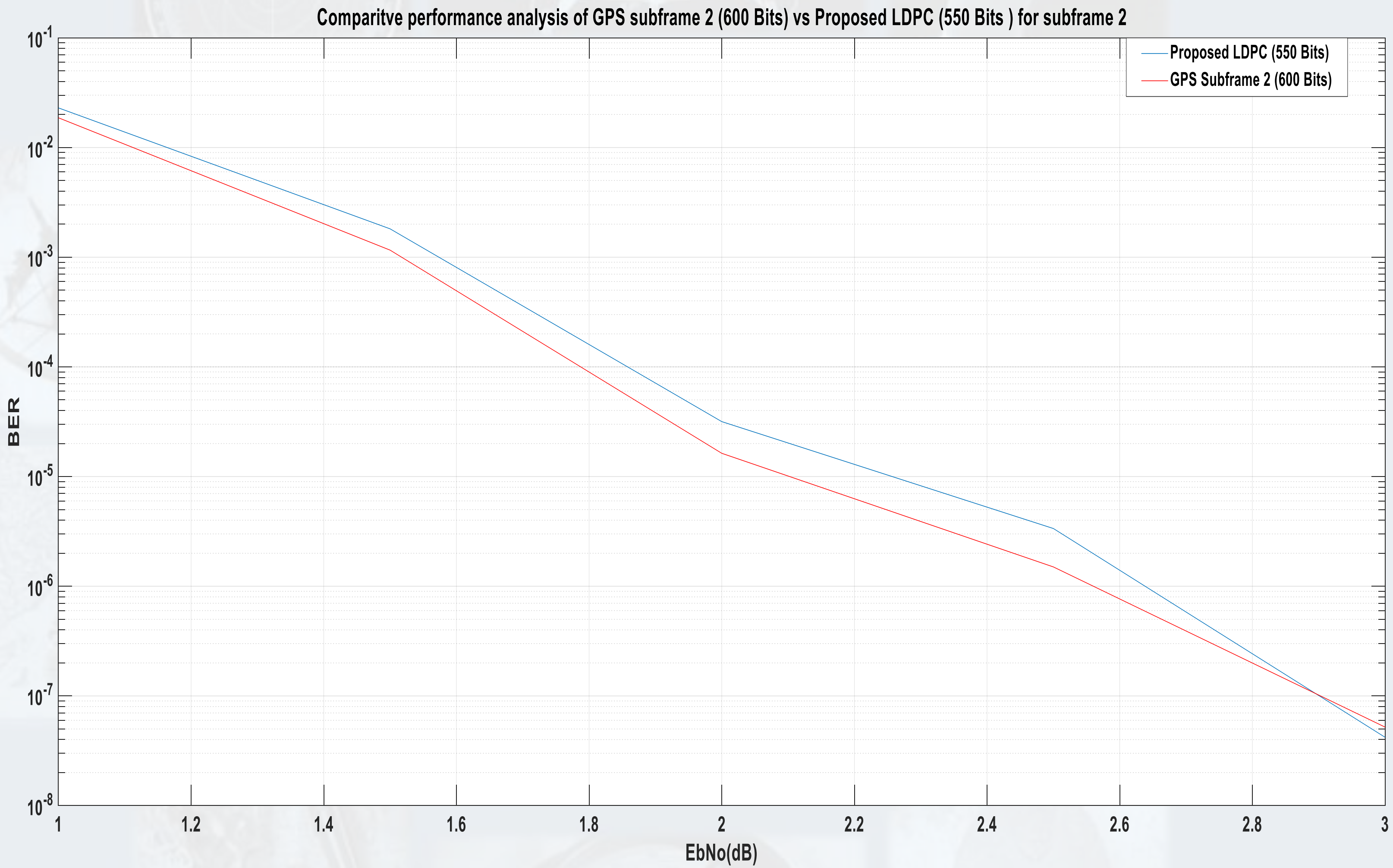




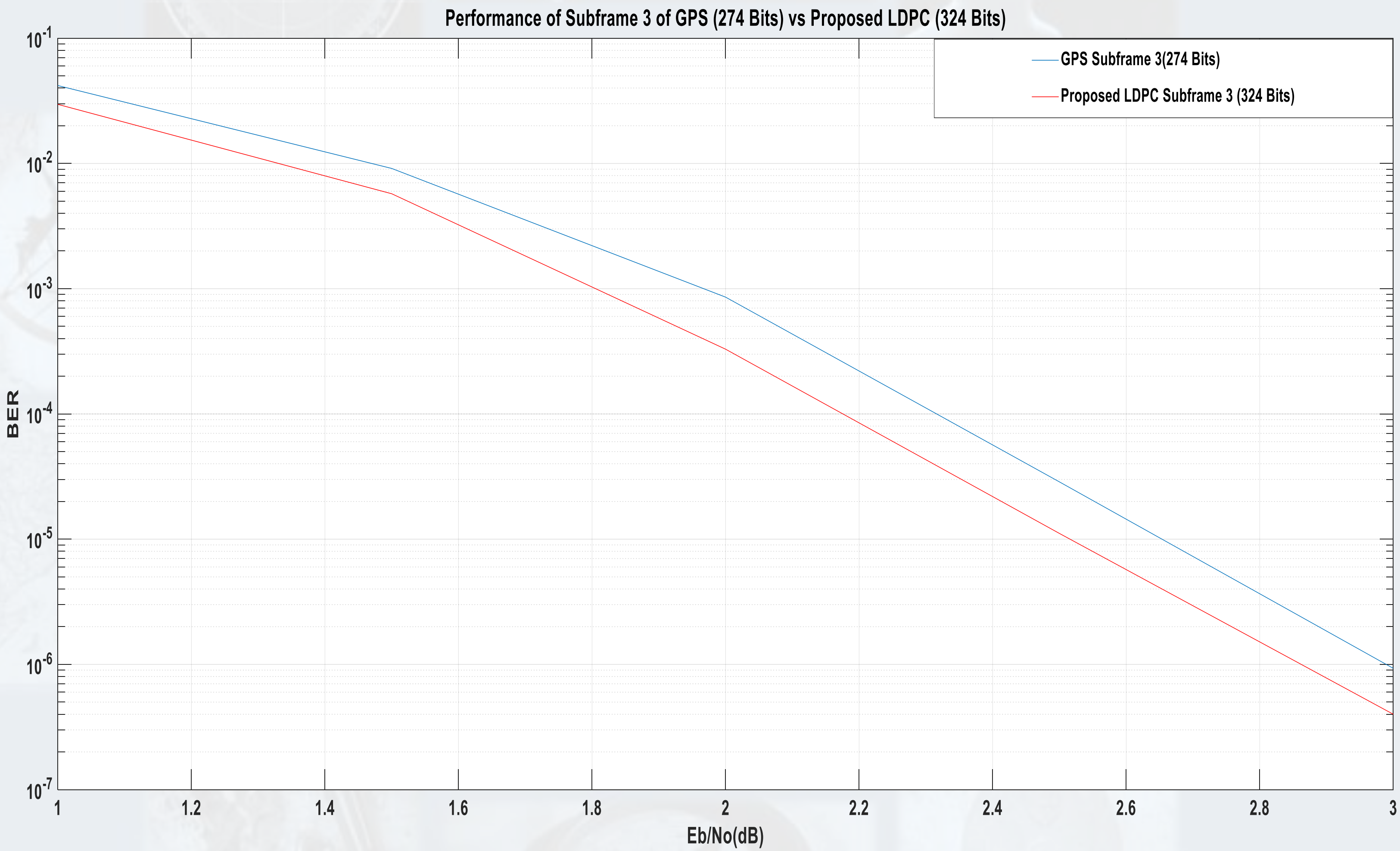
550X1100 LDPC PARITY MATRIX DISTRIBUTION







Comparitve performance analysis of GPS subframe 2 (600 Bits) vs Proposed LDPC (550 Bits) for subframe 2
Proposed LDPC (550 Bits)
GPS Subframe 2 (600 Bits)
BER
EbNo(dB)
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3


Performance of Subframe 3 of GPS (274 Bits) vs Proposed LDPC (324 Bits)
GPS Subframe 3(274 Bits)
Proposed LDPC Subframe 3 (324 Bits)
BER
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
Eb/No(dB)

Third Party validation result

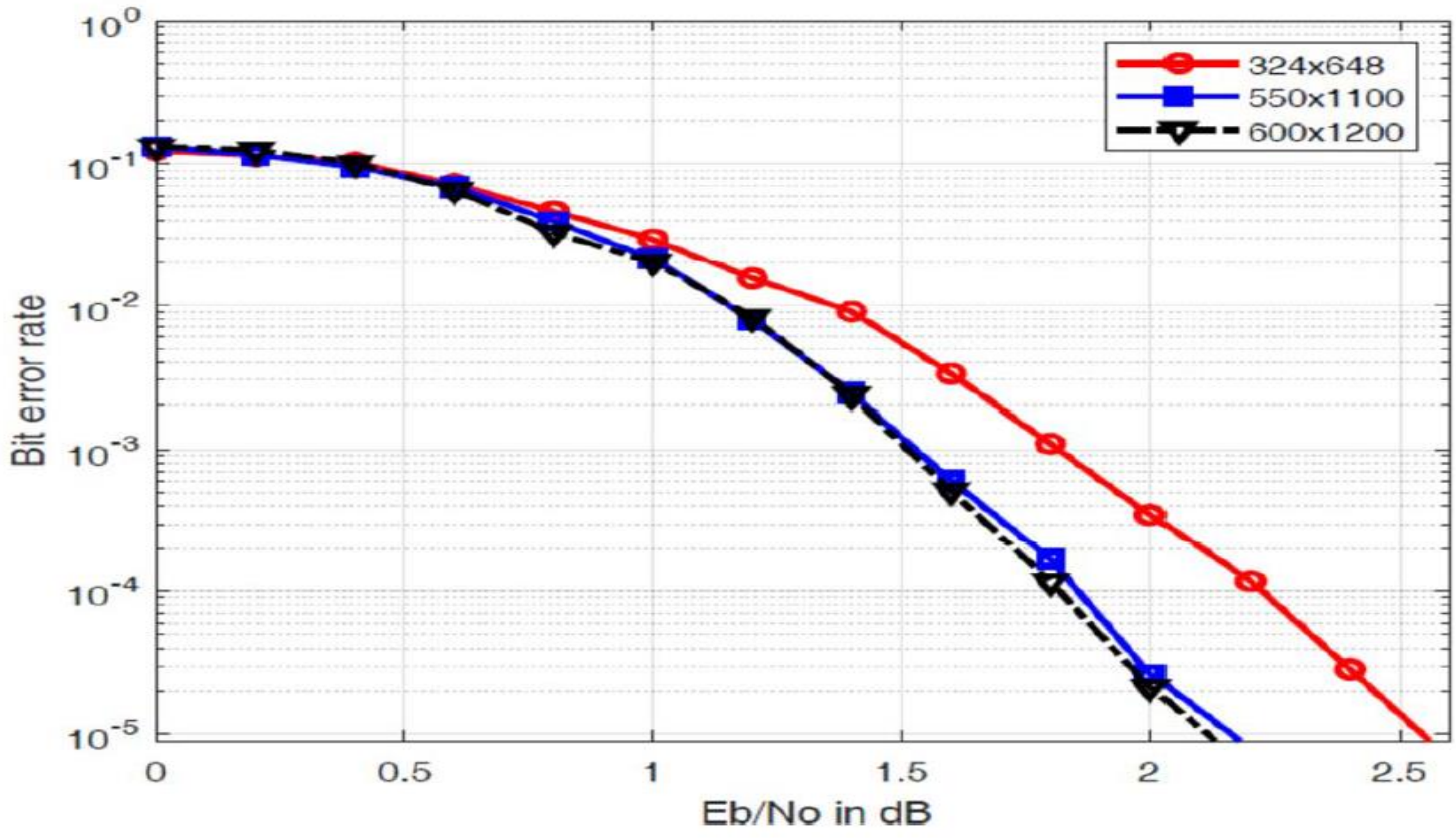


Fig. 1: BER performance of proposed QC-LDPC codes for Subframe length 324,550 and 600 Bits

References

References: -

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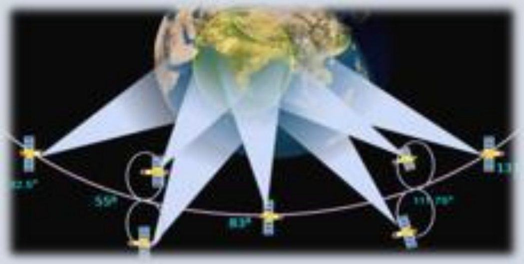
2. Qian H, Li GX, Chang J (2011) Application of quasi-cycle low-density parity check codes with high performance to satellite navigation signals. J Comput Appl 31(4):1145–1147.
3. 3GPP, "Document 3GPP chairman'notes 3GPP TSG RAN WG1 meeting 87," 2016, https://www.3gpp.org.
4. Li Z, Chen L, Zeng L et al (2006) Efficient encoding of qusai-cyclic low-density parity-check codes. IEEE Trans Comm 54(1):P71–P81.
5. GPS Navstar Joint Program Office. Navstar GPS space segment/user segment L1C interfaces[S], Draft IS-GPS-800, 2006.




Thank You