Novel Modulation, Coding and Soft decoding algorithms for NavIC L1 Receivers

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Abstract

- Synthesized binary offset carrier (SBOC) modulation scheme and Quasi cyclic LDPC code are proposed for future IRNSS L1 civilian signal. SBOC modulation contains the data signal and pilot signal. Both data and pilot signals contains the BOC(1,1) and BOC(6,1) components. A LDPC decoder required a log likelihood ratio (LLR) based inputs from demodulator of user receiver to achieve maximum performance.
- In this presentation a novel log likelihood ratio (LLR) based interface algorithm is proposed for efficient implementation between SBOC demodulator and LDPC decoder in order to achieve maximum coding gain. The classical interface block diagram of any modulator and demodulator with LDPC Encoder and decoder is shown in figure 1.

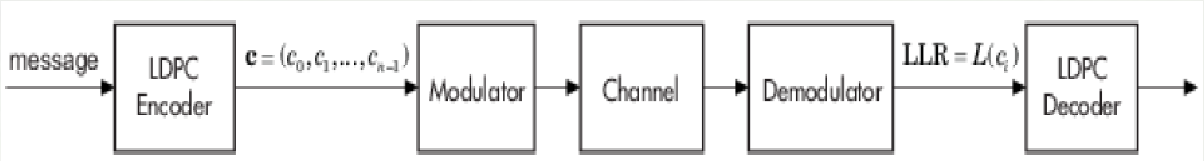
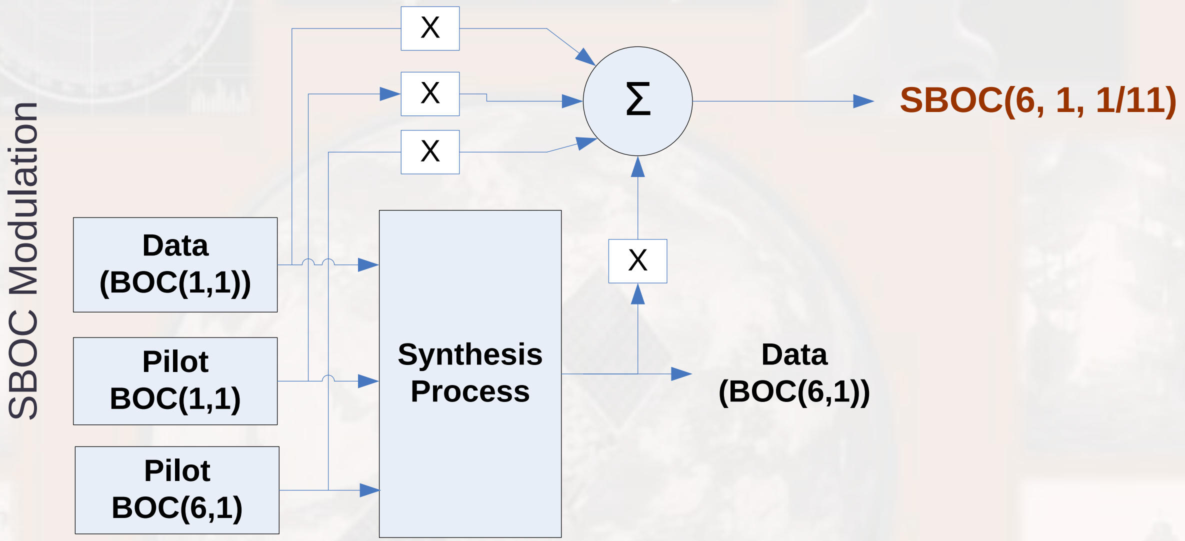


Figure 1 : LDPC Encoder and Decoder interface with modulator and demodulator

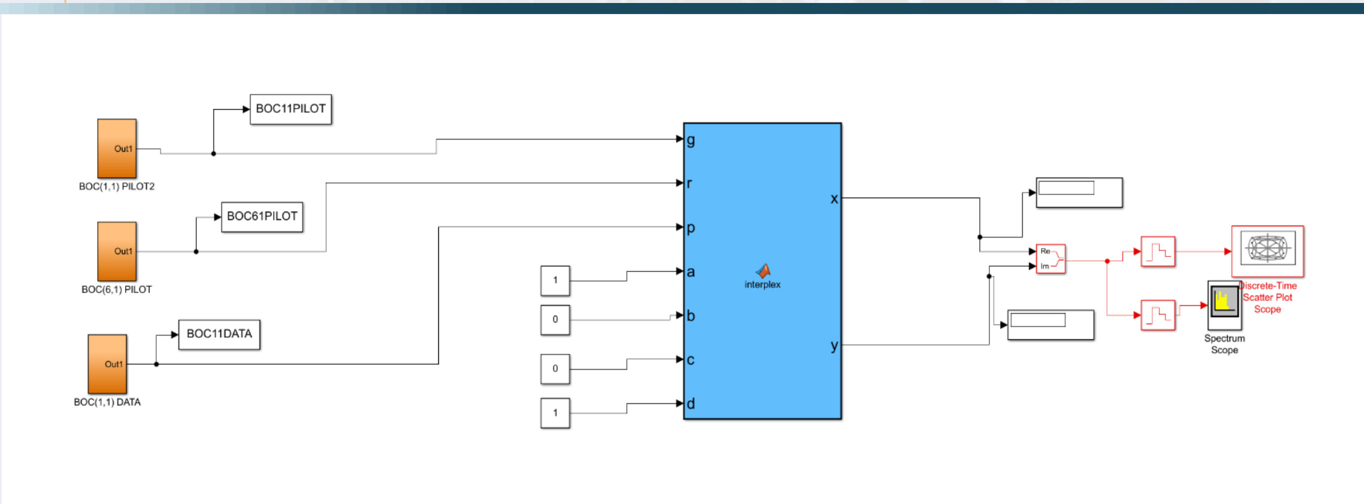
Synthesized BOC (SBOC) Generation Method

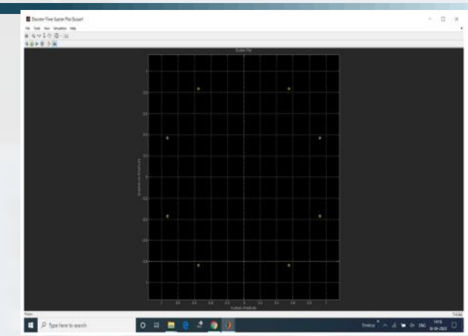


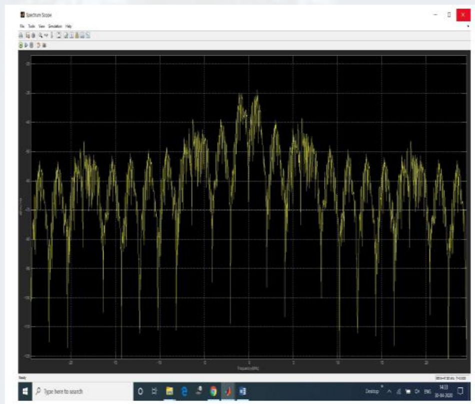
$$\boldsymbol{SBOC}: \boldsymbol{S}(\boldsymbol{t}) = \left[\propto \boldsymbol{S}_{\boldsymbol{p1}}(\boldsymbol{t}) - \boldsymbol{\beta}\boldsymbol{S}_{\boldsymbol{p2}}(\boldsymbol{t})\right] + \boldsymbol{j}[\boldsymbol{\gamma}\boldsymbol{S}_{\boldsymbol{d1}}(\boldsymbol{t}) + \boldsymbol{\eta}\boldsymbol{S}_{\boldsymbol{d2}}(\boldsymbol{t})]$$

- α, β, γ, η are optimized to get constant envelope and meet PSD requirements.
  - Constraints: $\alpha^2 + \beta^2 + \gamma^2 + \eta^2 = 1$, $\alpha^2 + \gamma^2 = 10/11$, $\beta^2 + \eta^2 = 1/11$
  - Optimum Power Sharing: $\alpha^2 = 6/11$, $\beta^2 = 4/110$, $\gamma^2 = 4/11$, $\eta^2 = 6/110$

Synthesized BOC (SBOC) Generation Method







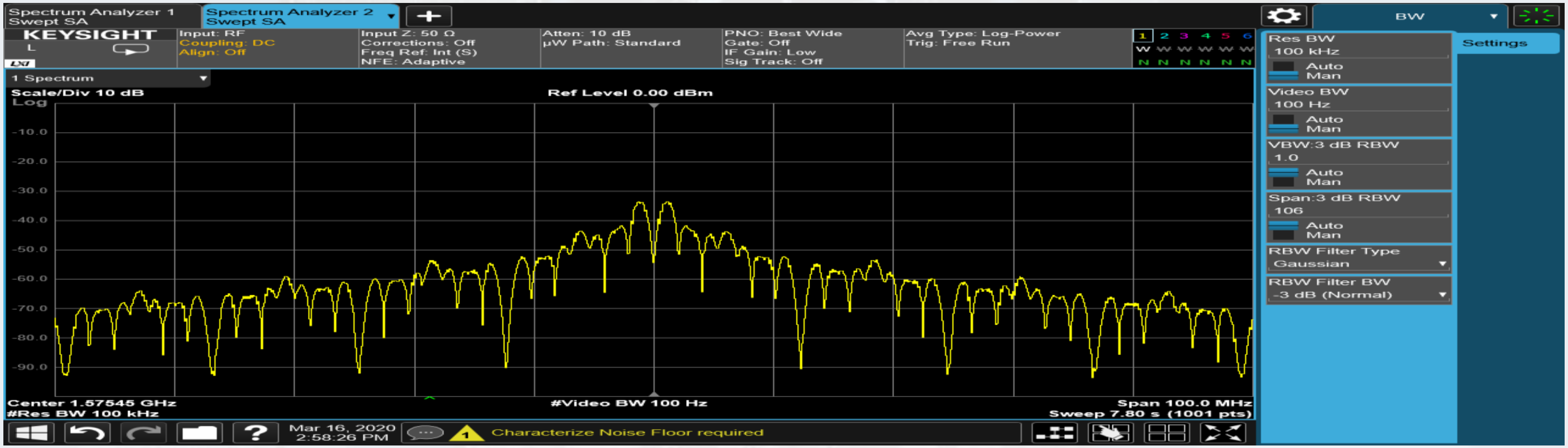
$$SBOC: S(t) = [\propto S_{BOC(1,1)p}(t) - \beta S_{BOC(6,1)p}(t)] + j[\gamma S_{BOC(1,1)d}(t) + \eta S_{BOC(6,1)d}(t)]$$

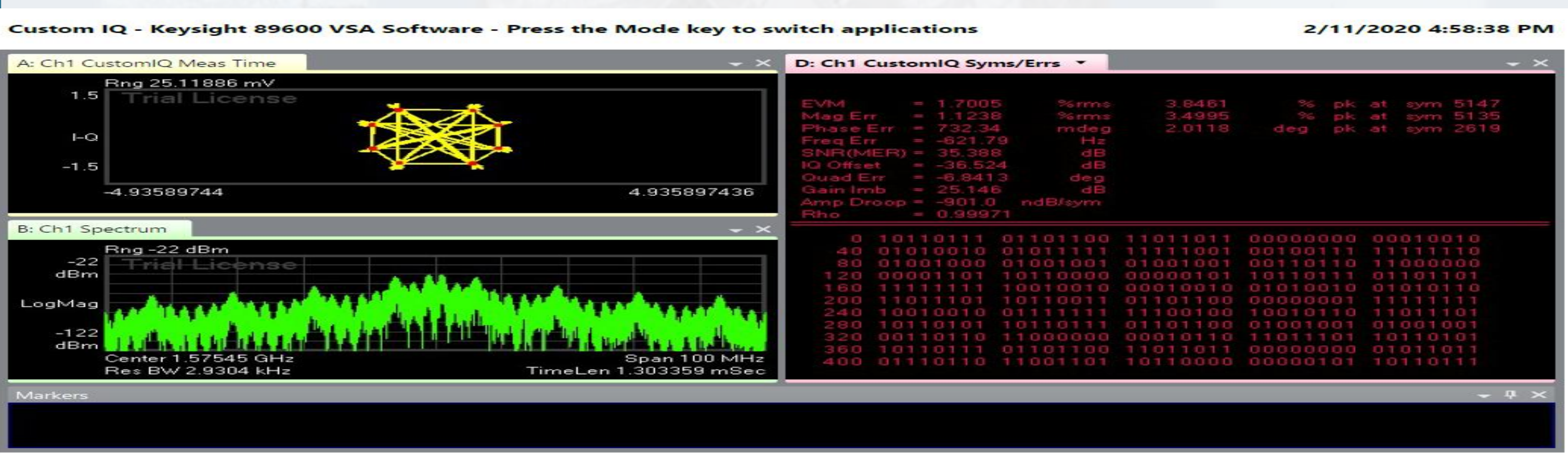
Table 1: Look up table based SBOC Modulation

Pilot BOC(1,1)	Pilot BOC(6,1)	DATA BOC(1,1)	I	Q
-1	-1	-1	-0.547856428	-0.836572372
-1	-1	1	-0.547856428	0.836572372
-1	1	-1	-0.929241464	-0.369473006
-1	1	1	-0.929241464	0.369473006
1	-1	-1	0.929241464	-0.369473006
1	-1	1	0.929241464	0.369473006
1	1	-1	0.547856428	-0.836572372
1	1	1	0.547856428	0.836572372

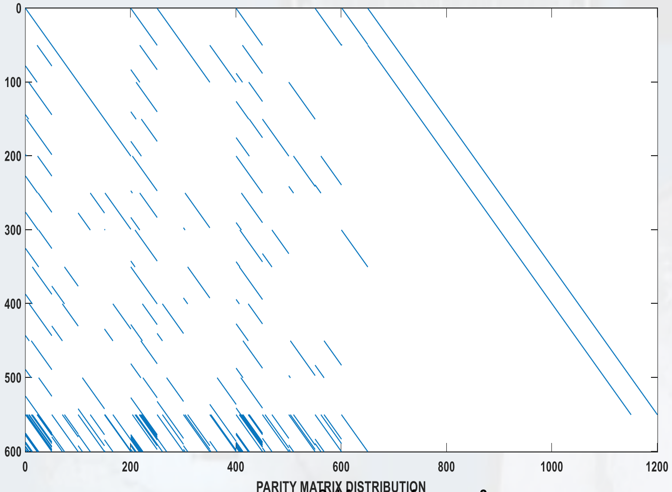
a b c d	MODULATION
1 0 0 0	SBOC
1 0 0 1	PILOT
1 0 1 0	DATA
1 0 1 1	BOC11 PILOT
1 1 0 0	BOC61 PILOT
1 1 0 1	BOC11 DATA
1 1 1 0	BOC61 DATA
1 1 1 1	PLAIN CARRIER

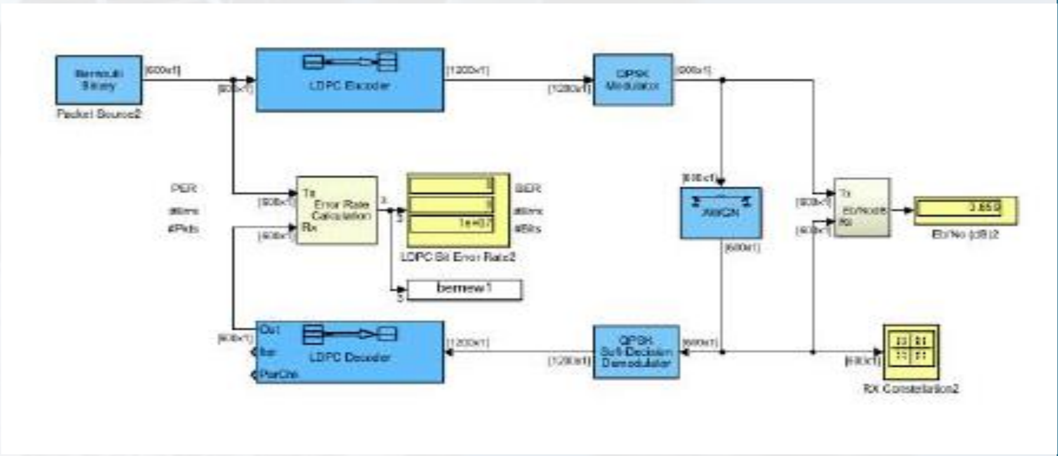
Synthesized BOC (SBOC) Generation Method



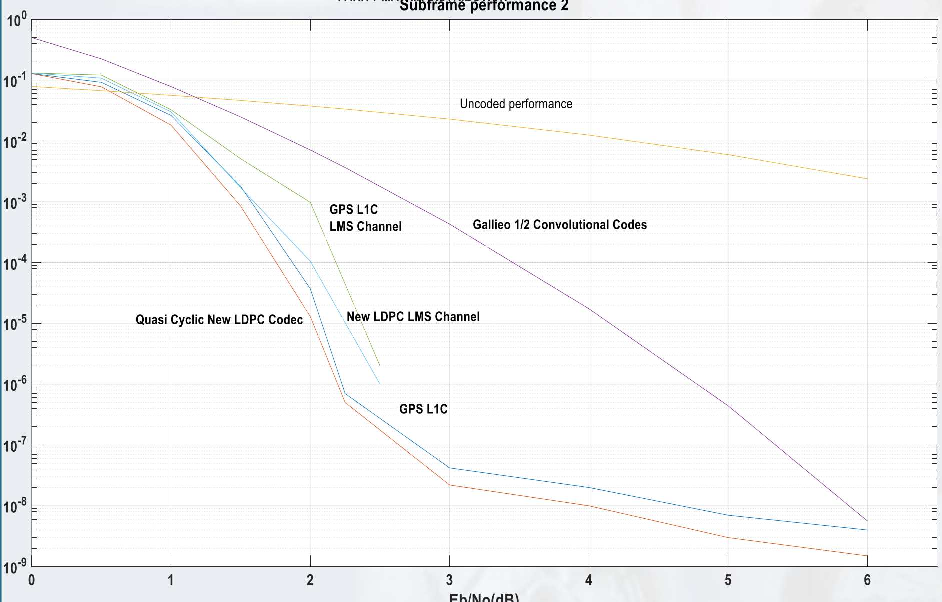


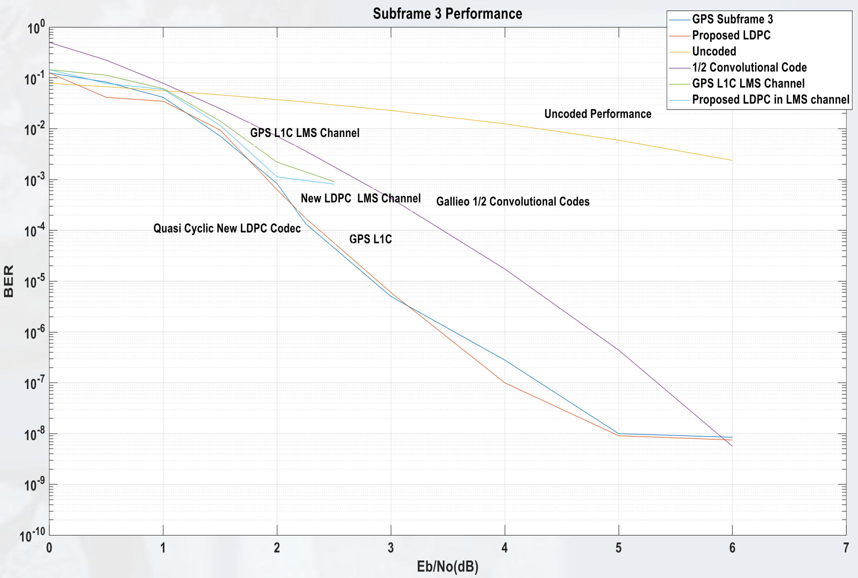
LDPC CODES FOR NavIC L1C



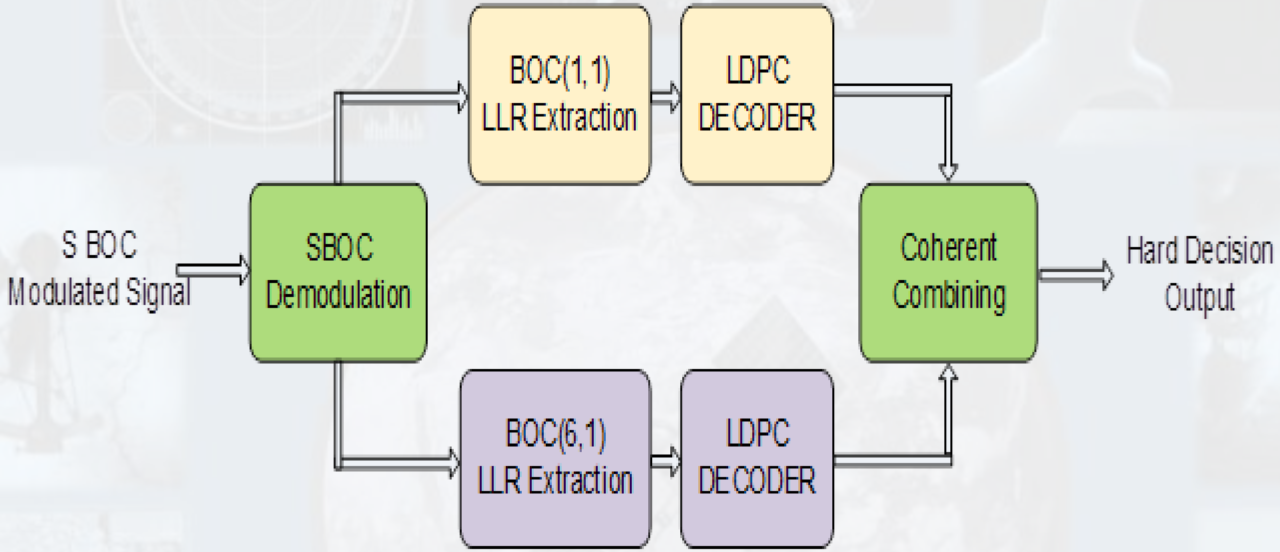


Belief propagation algorithm





Classical LLR based SBOC demodulator and LDPC decoder



Followings are drawback of the classical LLR decoding.

- Hardware resources requirement is large as its required separate extraction of BOC (1,1) and BOC (6,1) LLRs along with two separate LDPC decoder.
- Coherent combining of two separate LDPC decoder.
- Difficult to achieve maximum coding gain.
- The necessity of complex synchronization with increased latency.

Proposed Approach

Approximate LLR is computed by using only the nearest constellation point to the received signal with a 0 (or 1) at that bit position, rather than all the constellation points as done in true LLR. It is defined as:

$$L(b) = -\frac{1}{\sigma^2}\left(\min_{s\in S_0}\left((x-s_x)^2 + (y-s_y)^2\right) - \min_{s\in S_1}\left((x-s_x)^2 + (y-s_y)^2\right)\right)$$

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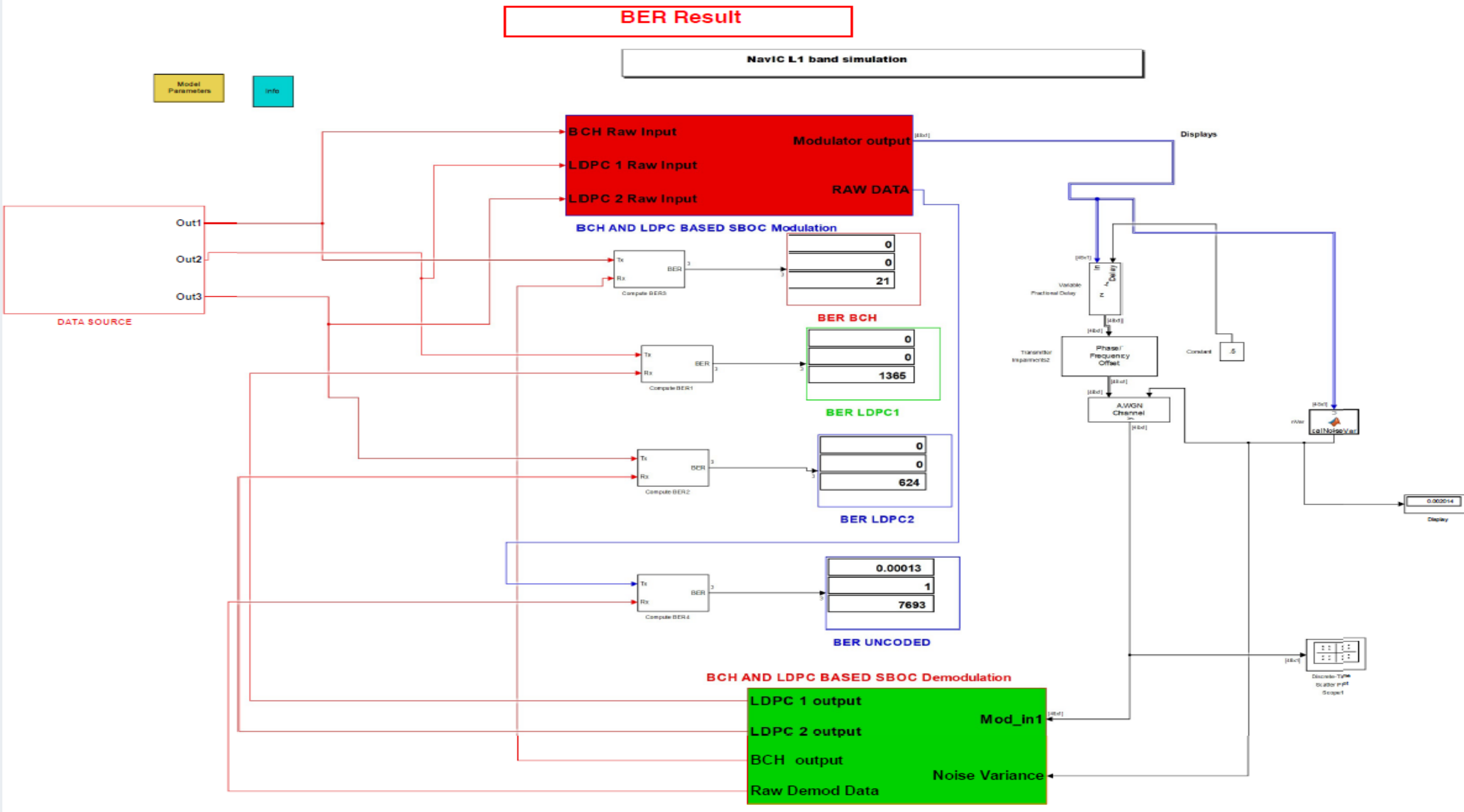
Advantages

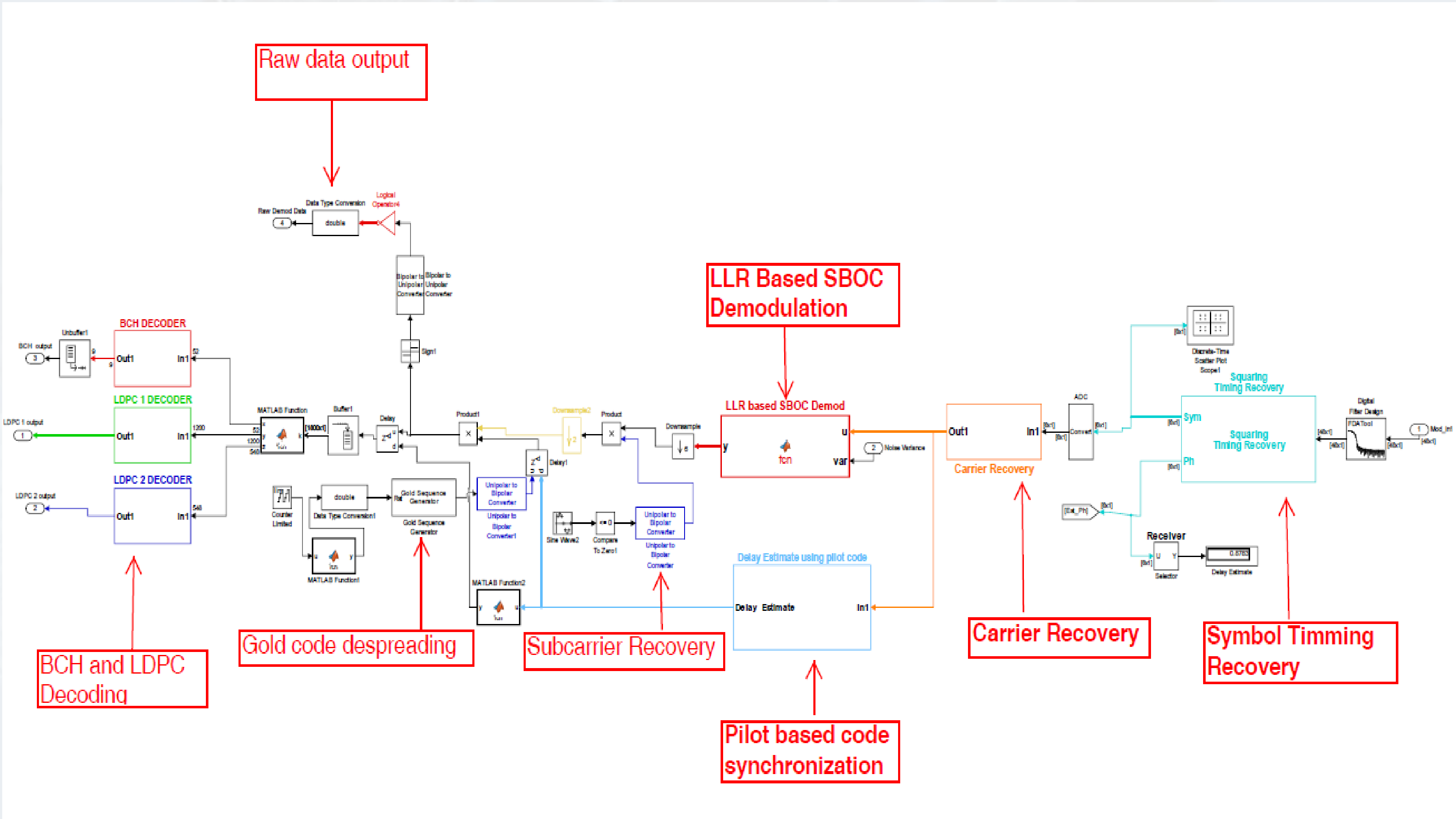
The proposed approach is having following advantages compare to classical approach: -

- Hardware simplification: As the proposed approach is LUT based So, it simplifies the hardware implementation.
- There will be only one LDPC decoder required compare to classical approach with two LDPC decoders.
- The use of single chain LLR design removes the requirement of coherent combining of the LDPC outputs which simplifies the implementation.
- Due to use of approximated LLR calculation, maximum coding gain can be achieved.
- Decoding algorithm is based upon LUT approach, hence there is a only requirement of change in look up table in case of power sharing of SBOC modulation change.

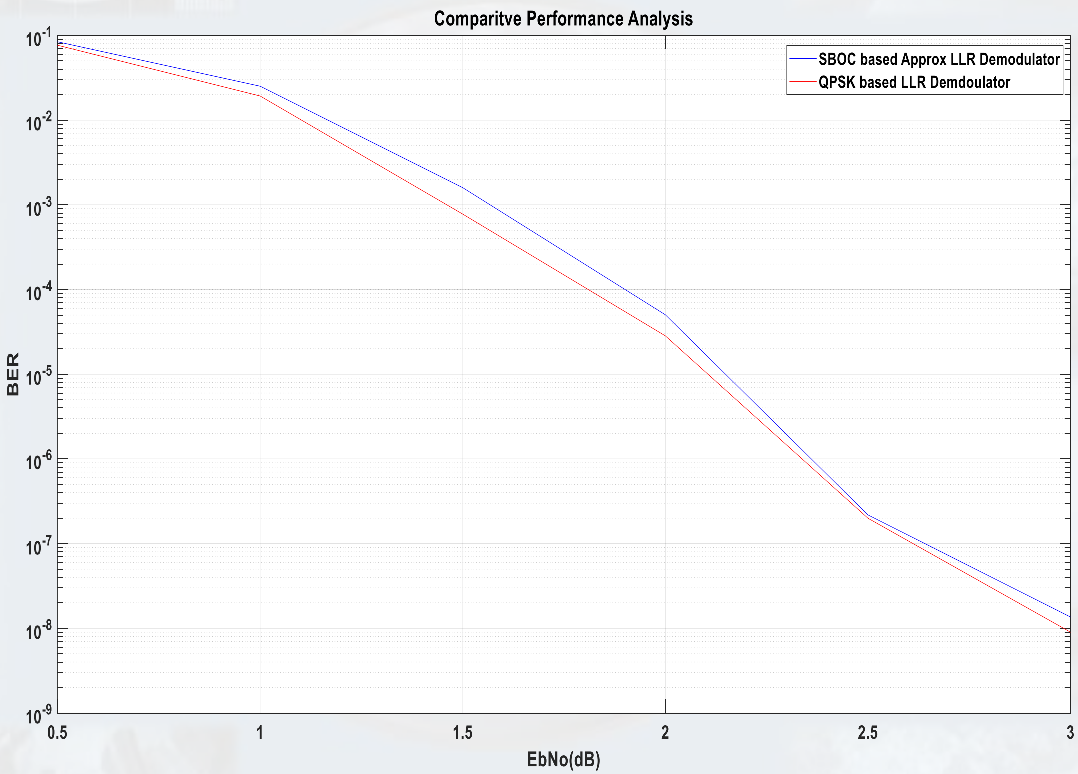
Verification Model



Verification Model



Simulation Result



Patent

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(51) International classification	:H03M0013110000, H04N0019960000, H04L0005140000, G06F0011340000, H04L0027060000	(71)**Name of Applicant :** **1)Indian Space Research Organisation** Address of Applicant :Department of Space, Antariksh Bhavan, New BEL Road, Bangalore 560094, India Karnataka India (72)**Name of Inventor :** **1)Dr Deepak Mishra** **2)Neeraj Mishra** **3)Sanjay D Mehta** **4)T.V.S Ram**
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(57) Abstract :
A novel log likelihood ratiobased interface algorithm for efficient implementation between synthesized binary offset carrier demodulator and low-density parity-check decoder in order to achieve maximum coding gain. The look-up table based log likelihood ratio decoding algorithm is proposed for minimizing the hardware requirement with achieving the maximum coding gain. The proposed approach is much simplified compare to other existing approaches and does not provide any degradation in the performance of demodulator. Figure 3

No. of Pages : 18 No. of Claims : 2

References

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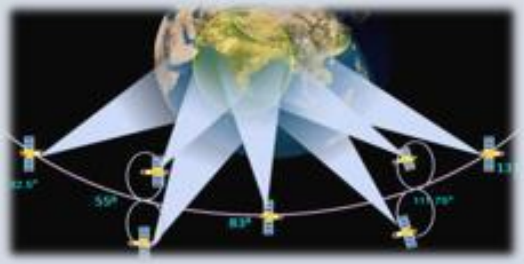
- [1] Rappaport, Theodore S. *Wireless Communications: Principles and Practice.* Upper Saddle River, NJ: Prentice Hall, 1996, pp. 238–248.

- [2] Viterbi, A. J. "An Intuitive Justification and a Simplified Implementation of the MAP Decoder for Convolutional Codes," *IEEE Journal on Selected Areas in Communications*. Vol. 16, No. 2, Feb. 1998, pp. 260–264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Thank You