Proposal for improvement of pilot signals S1 and S2 for 1000BASE-H

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Agenda

- Rational behind the current specifications (D1.2)
- Drawbacks of current specifications
- New proposal

Rational behind the current specification

- Pilot S1:
  - It is intended for optimum symbol synchronization: the receiver is able to easily detect the beginning of the transmit block
  - It consists of a pseudo-random sequence of PAM2 symbols: simple implementation of correlator based on adders tree
  - The sequence is large enough for low variance detection
  - It is prefixed and suffixed by zero symbol sequences able to contain full channel response for seamless integration of THP processing used for payload data blocks equalization
  - Initialization of LFSR randomly selected for low correlation with PHS sub-blocks
- Pilot S2:
  - Consistent of multilevel PAM signals intended to excite the non-linear channel response enabling the receiver for non-linear channel estimation and compensation
  - Size of PAM signal set was chosen 256, trying to emulate PAM16 THP signal that is object of equalization
  - As S1 signal, each S2 pilot sub-block is prefixed and suffixed with zero sequences for easy integration with THP payload data blocks
  - No special attention was paid to LFSR initialization

Drawbacks of current S1 and S2 specification

- S1 and S2 sub-blocks: sum of sequence is NOT zero

$$\sum_{i=1}^{128} x_{s1}(i) \neq 0$$

$$\sum_{i=1+128(k-1)}^{128k} x_{s1,s2}(i) \neq 0 \quad \forall k \notin \mathbb{Z}, 1 \leq k \leq 13$$

  - Typically, optical receivers with good sensitivity are going to implement DC restoration circuits to optimize the noise, bandwidth and linearity characteristics of the TIA
  - Both, DC restoration and flicker noise (i.e. pink noise, 1/f), the last more important in sub-micron technologies, produce signal baseline-wander that has to be compensated by the PHY receiver
  - DC level deviation experienced by each pilot sequence depends on the data contained in the previous payload data blocks, which is a priori unknown

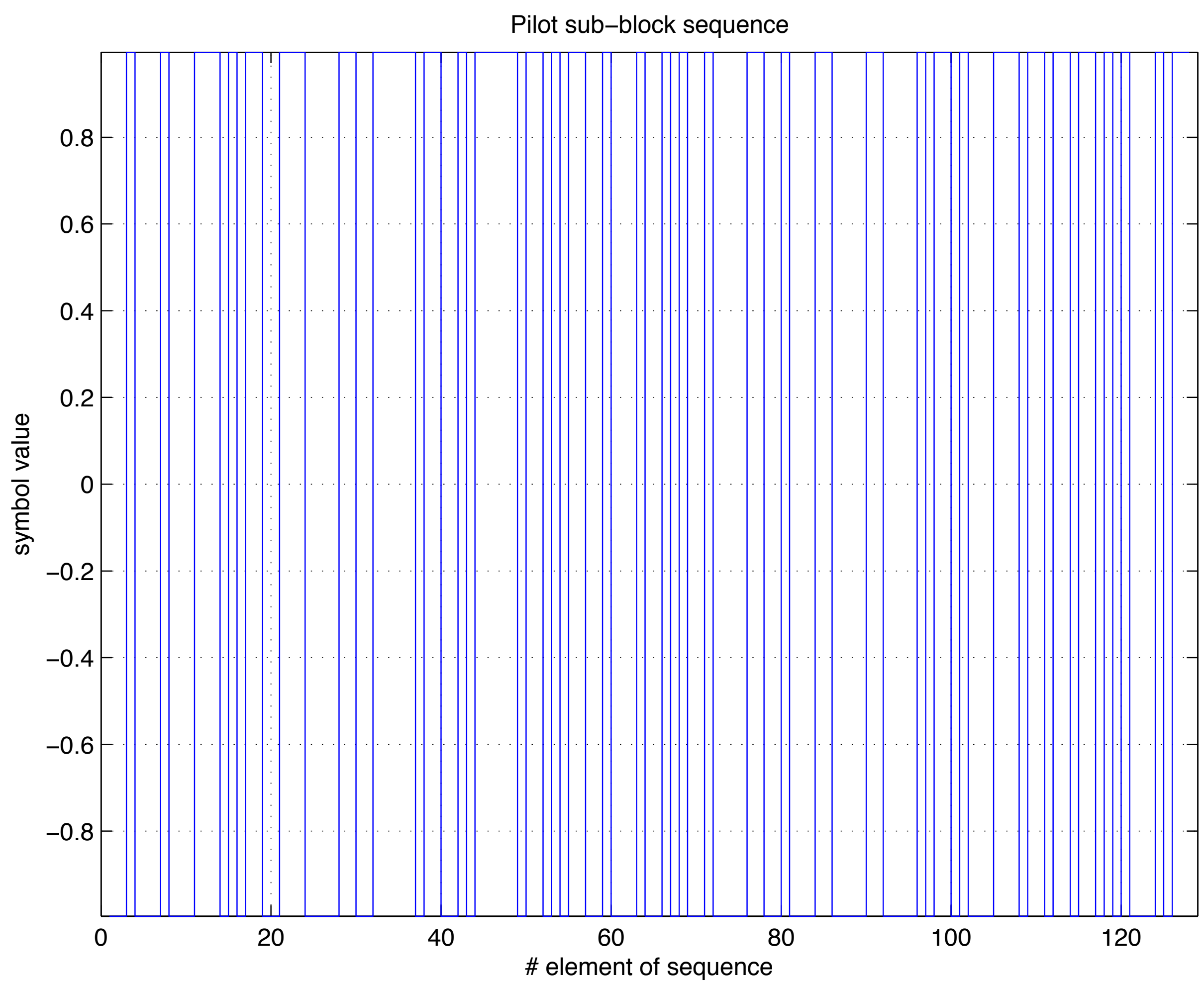
- S1 and S2 sub-blocks: cumulative sum (CS) is not controlled, therefore local average of each sequence presents large disparity

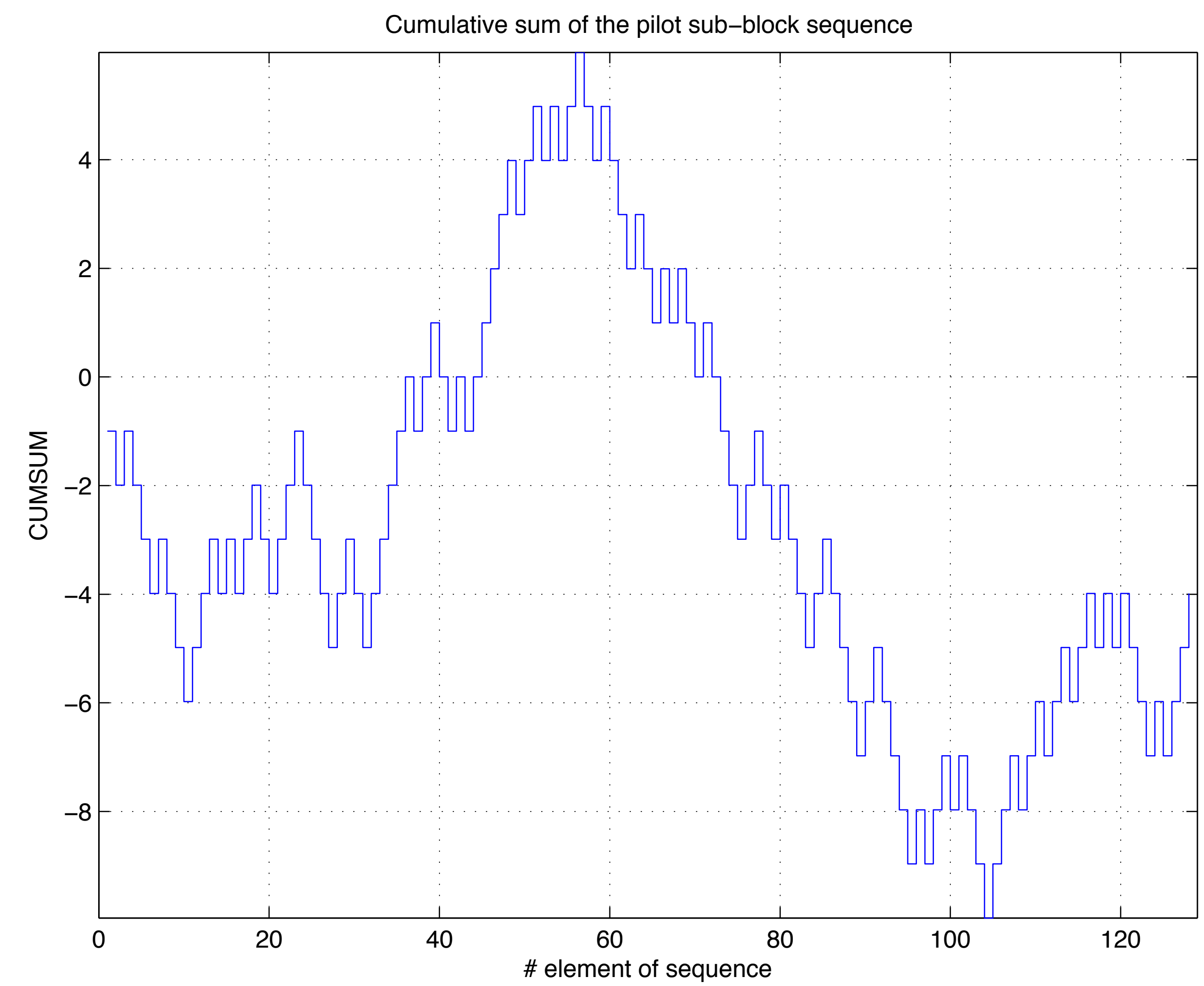
$$CS_x(j) = \sum_{i=1}^{j} x(i)$$

- S2 is modulated PAM256.
  - Large set of signals that makes difficult to get good spectral properties for each S2 sub-block
  - Main observation: each block is 128 symbols that take values from a set of 256 values

Drawbacks of current S1 and S2 specification

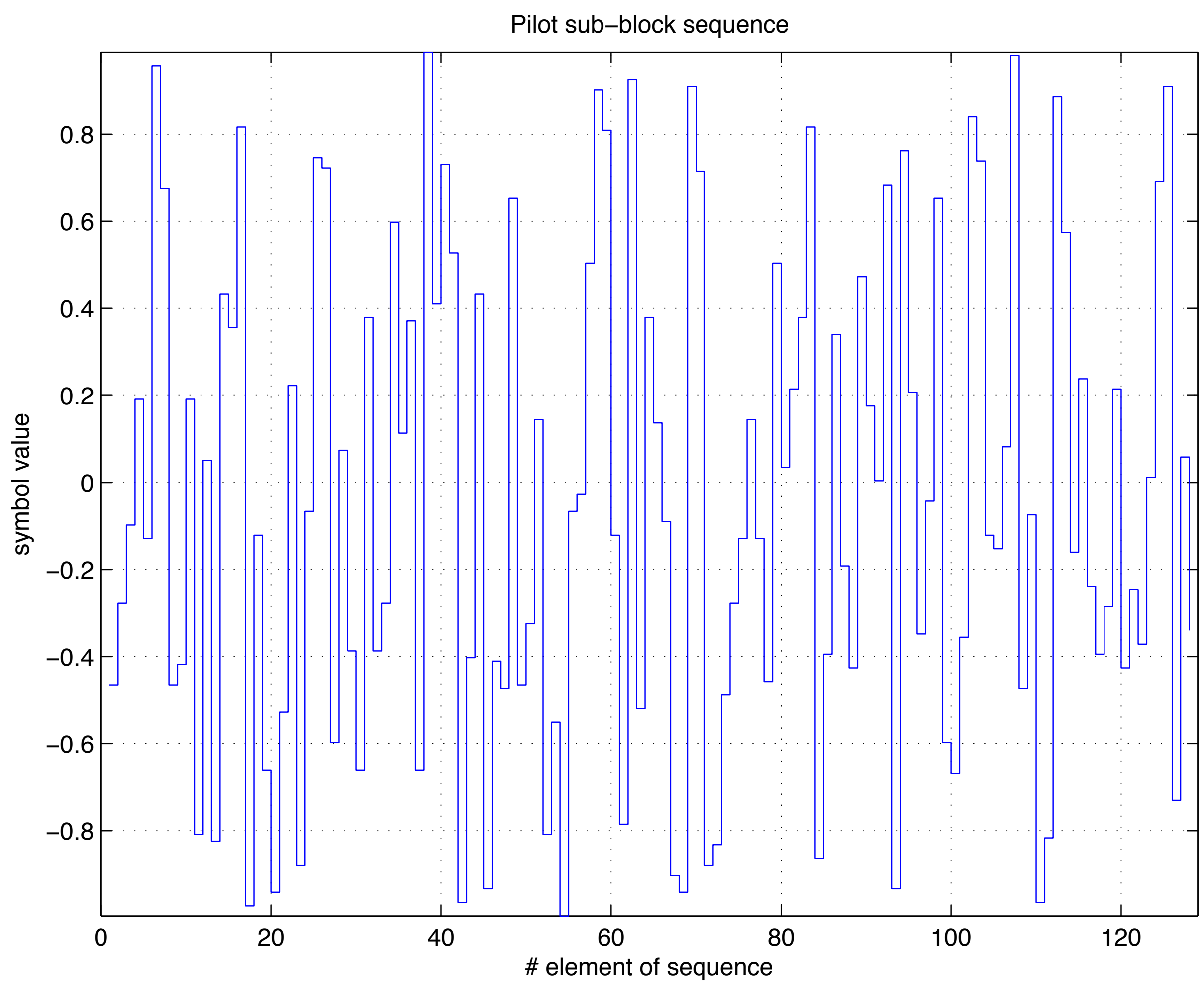
- Original S1: sum[x] = -3.98, E[CS_x] = -2.69, std[CS_x] = 3.78

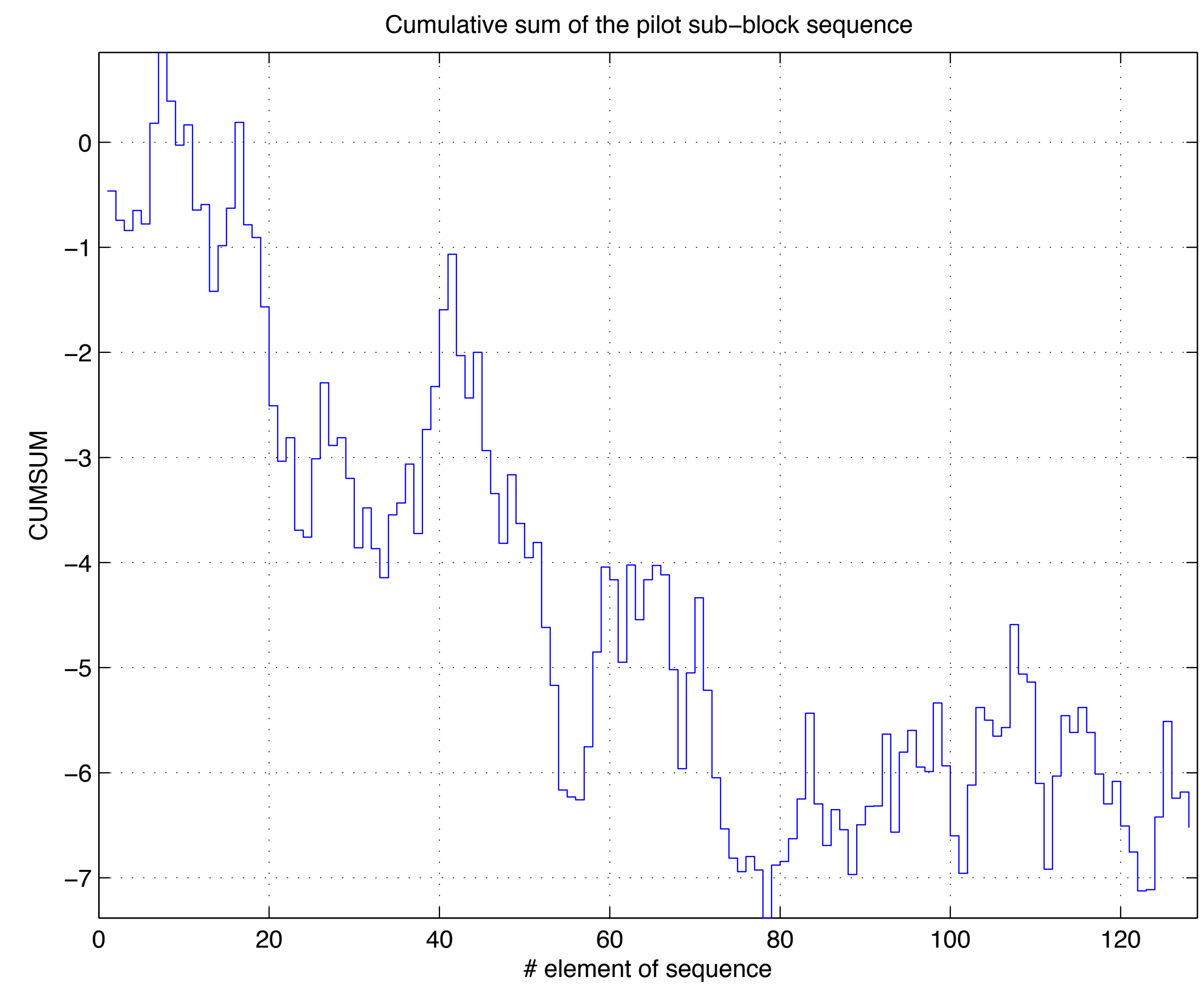




Drawbacks of current S1 and S2 specification

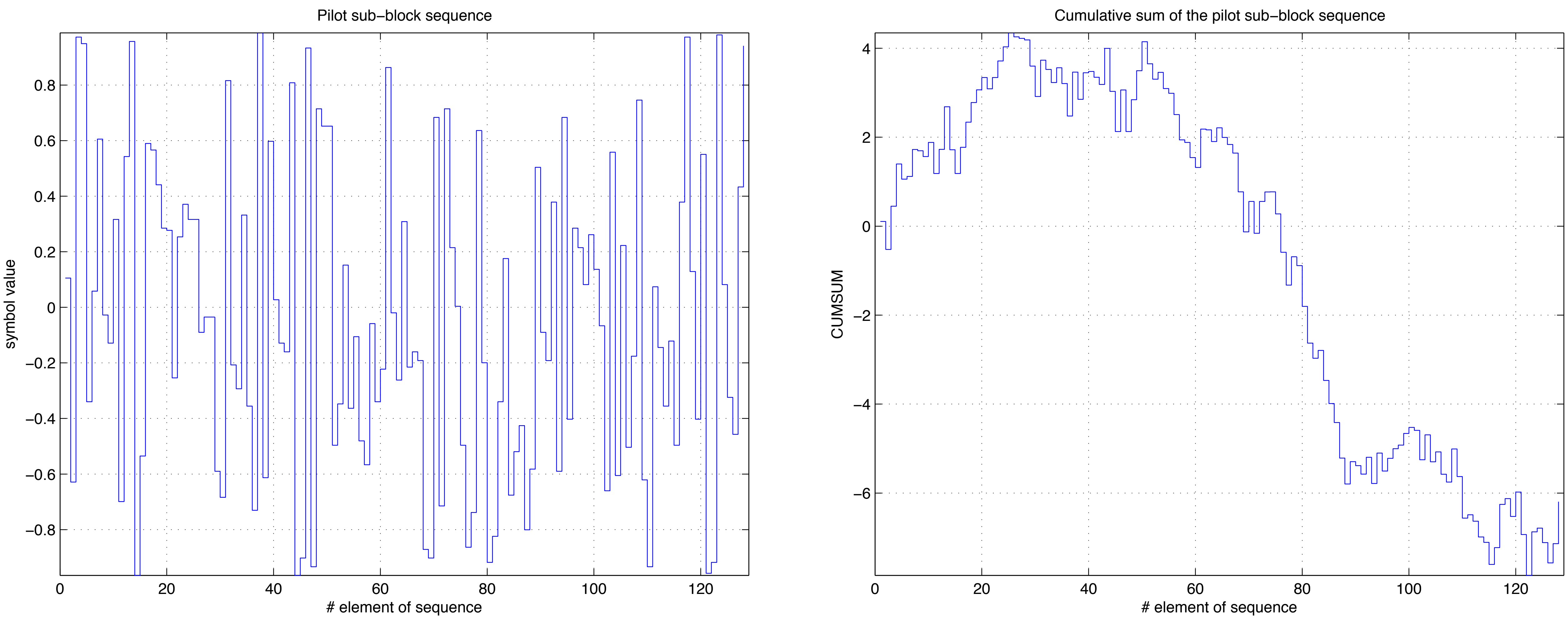
- Original $S2_0$: sum[x] = -6.52, E[CS_x] = -4.36, std[CS_x] = 2.16





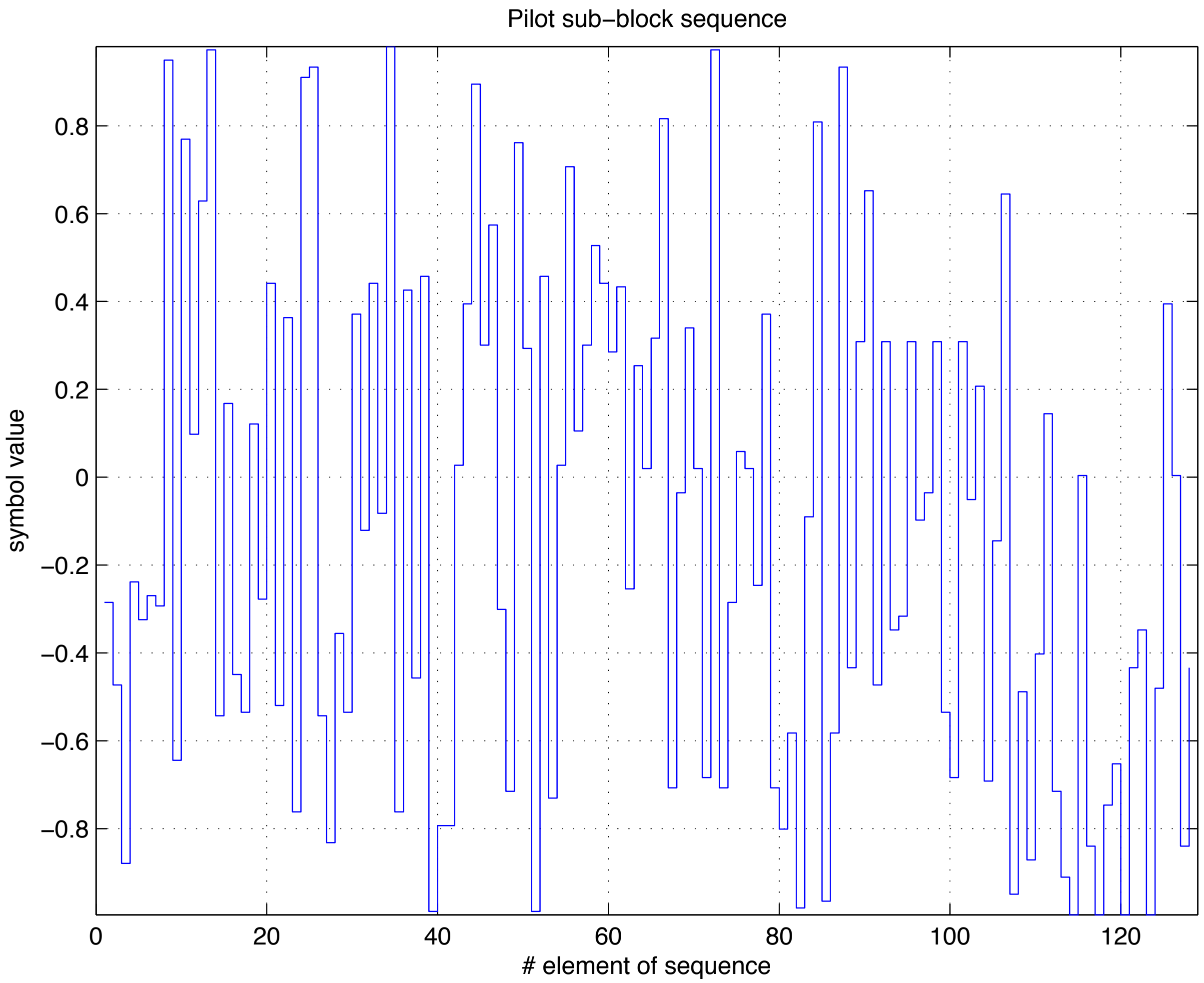
Drawbacks of current S1 and S2 specification

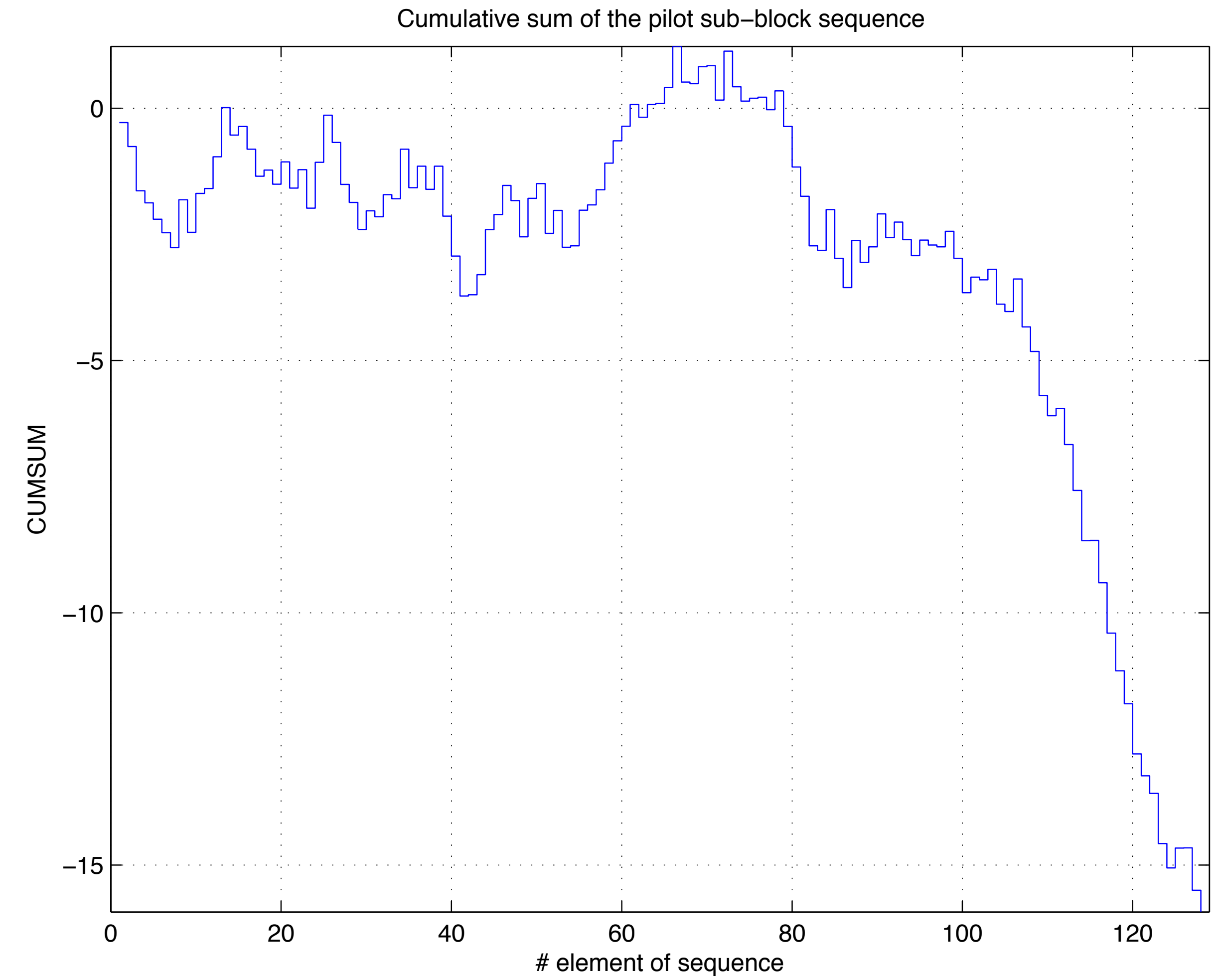
- Original $S2_1$: sum[x] = -6.19, E[CS_x] = -0.77, std[CS_x] = 4.02



Drawbacks of current S1 and S2 specification

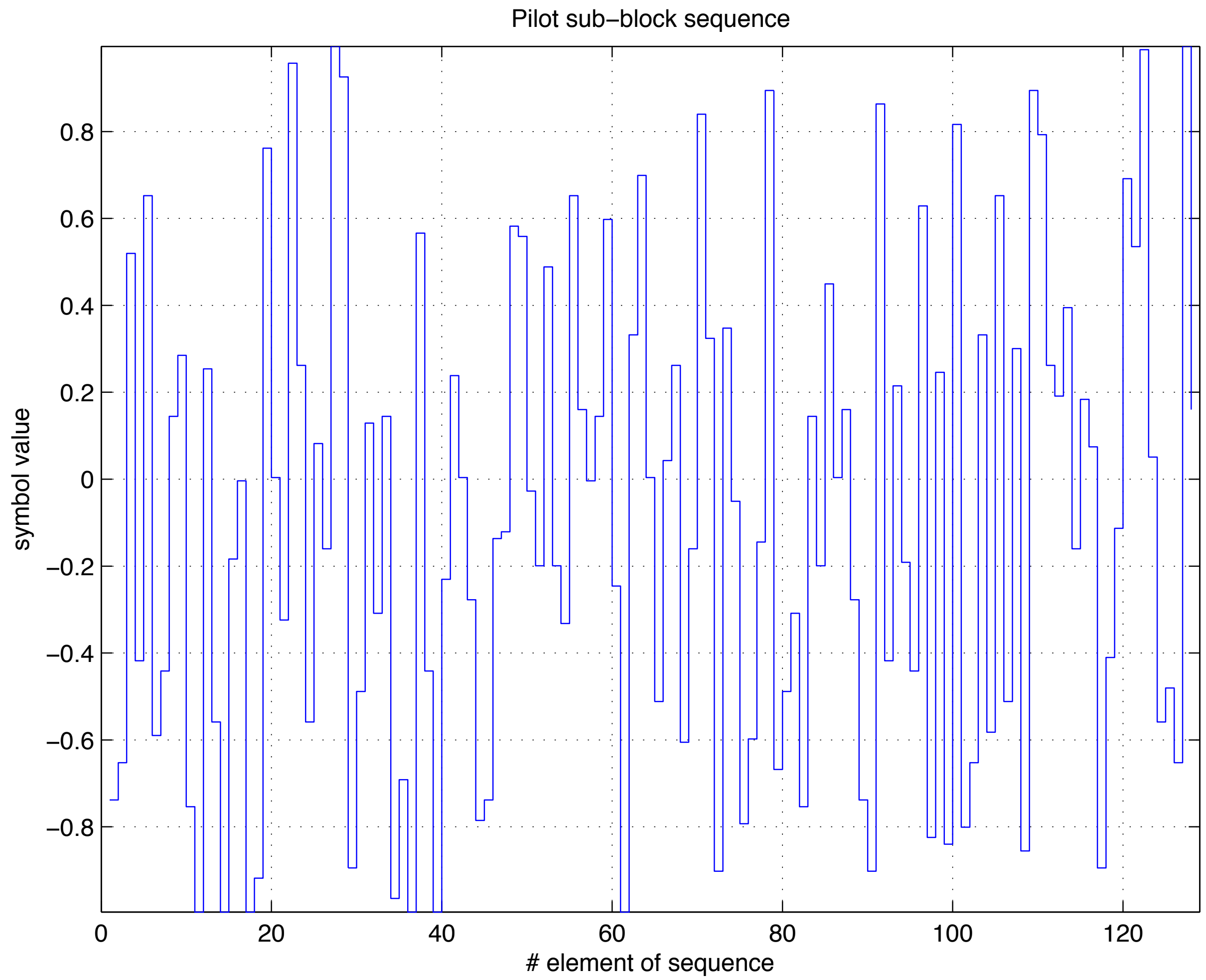
- Original $S2_2$: sum[x] = -15.9, E[CS_x] = -3.14, std[CS_x] = 3.89

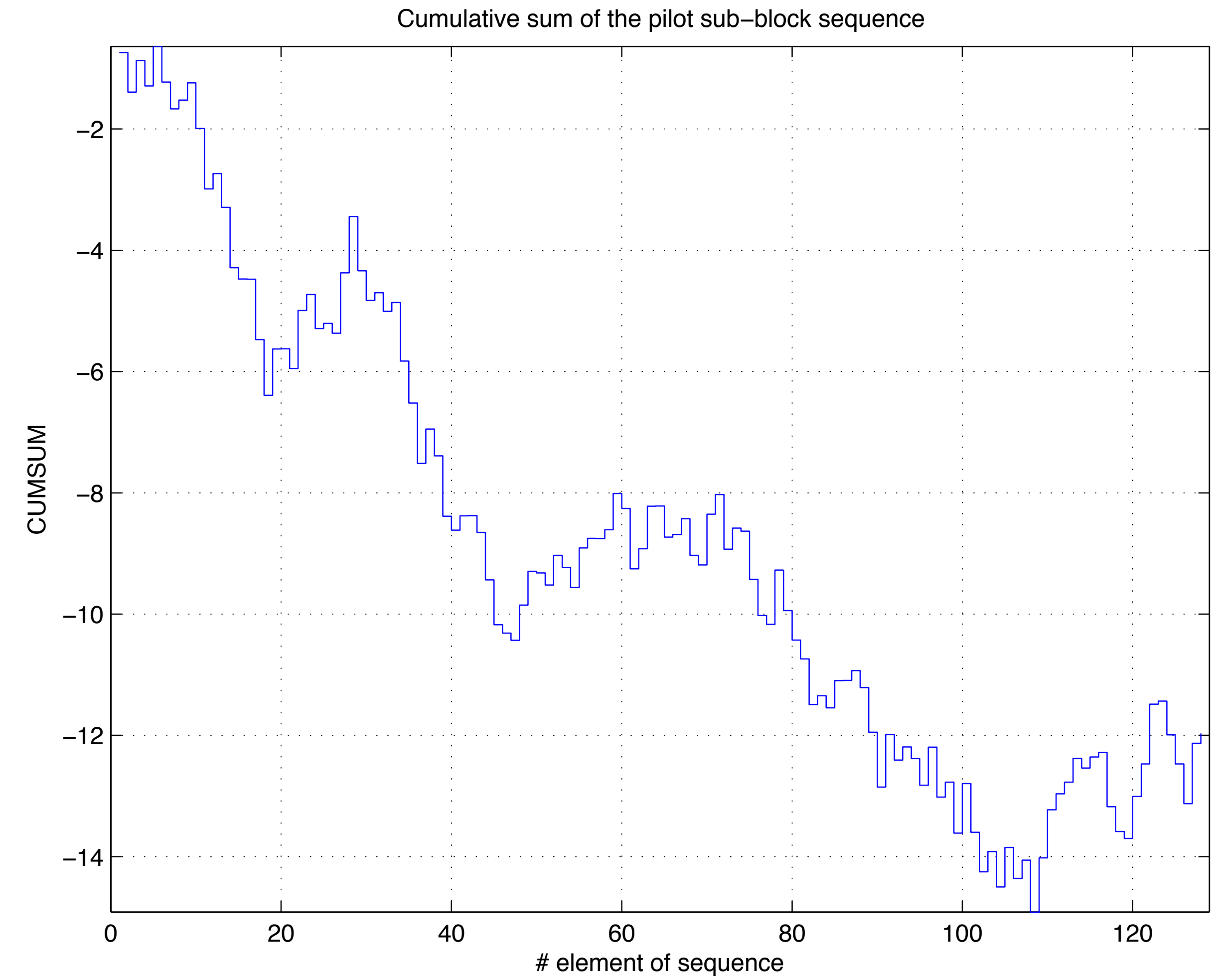




Drawbacks of current S1 and S2 specification

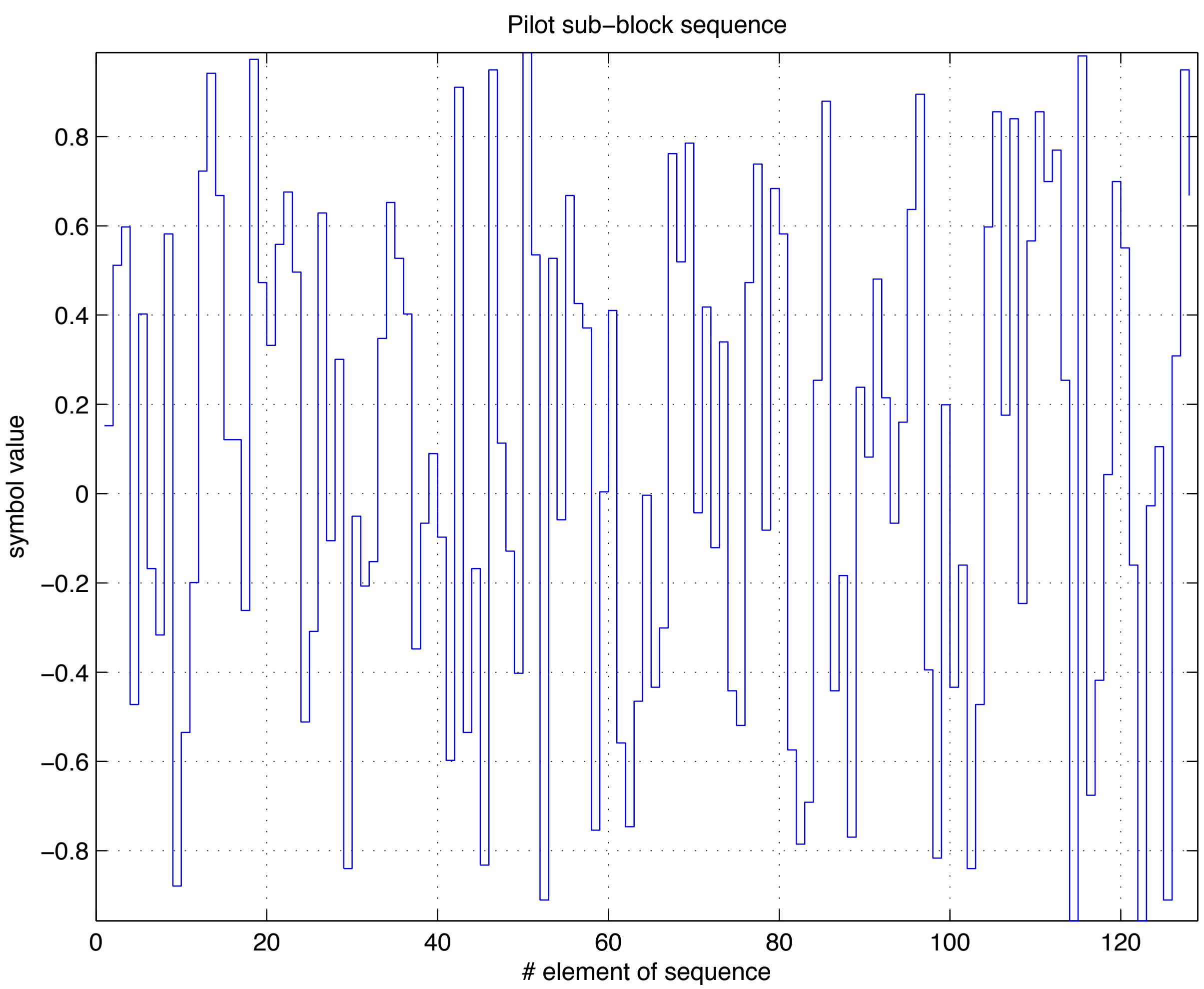
- Original $S2_3$: $sum[x] = -11.9$, $E[CS_x] = -8.9$, $std[CS_x] = 3.73$

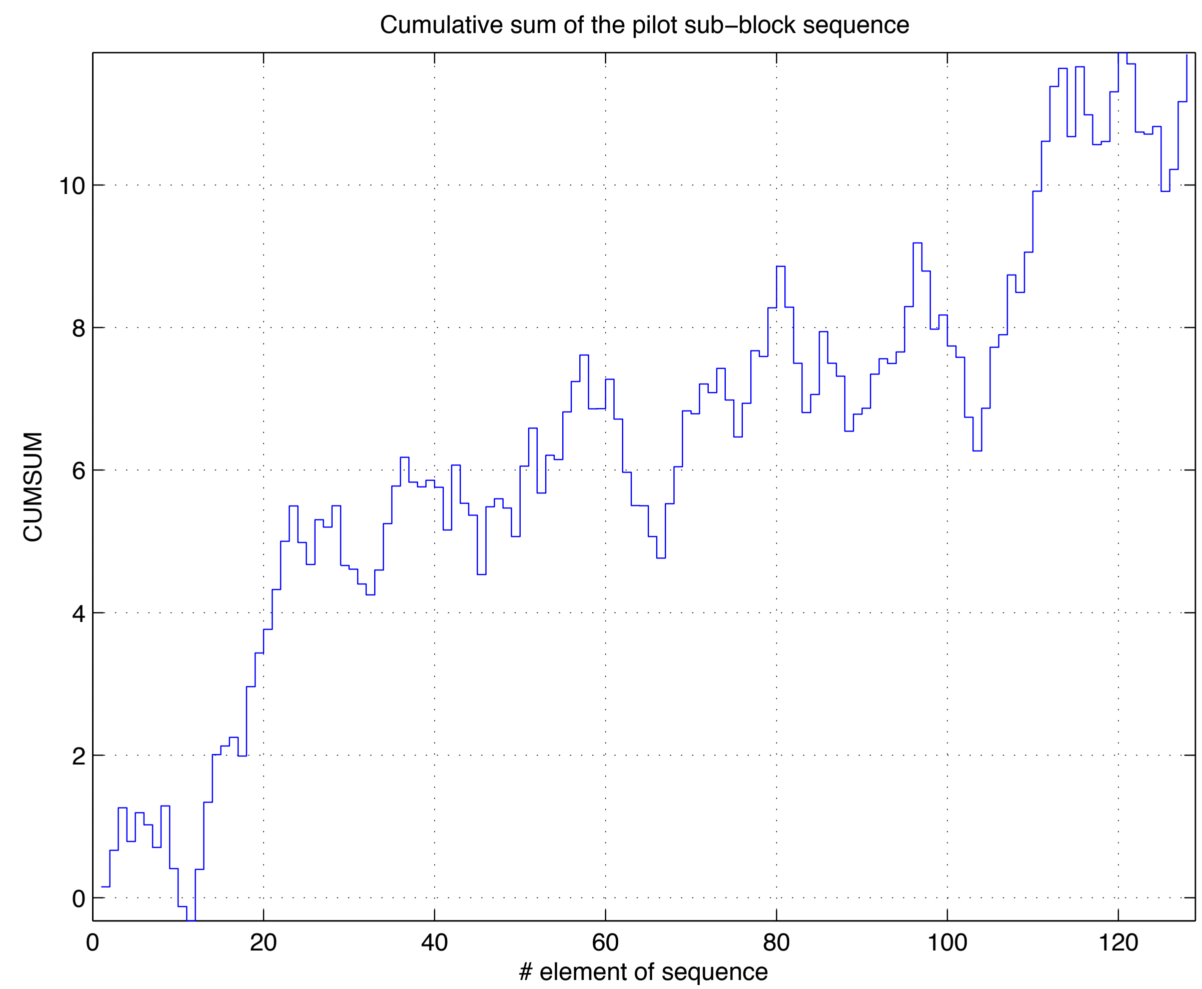




Drawbacks of current S1 and S2 specification

- Original $S2_4$: sum[x] = -11.8, E[CS_x] = 6.37, std[CS_x] = 2.90



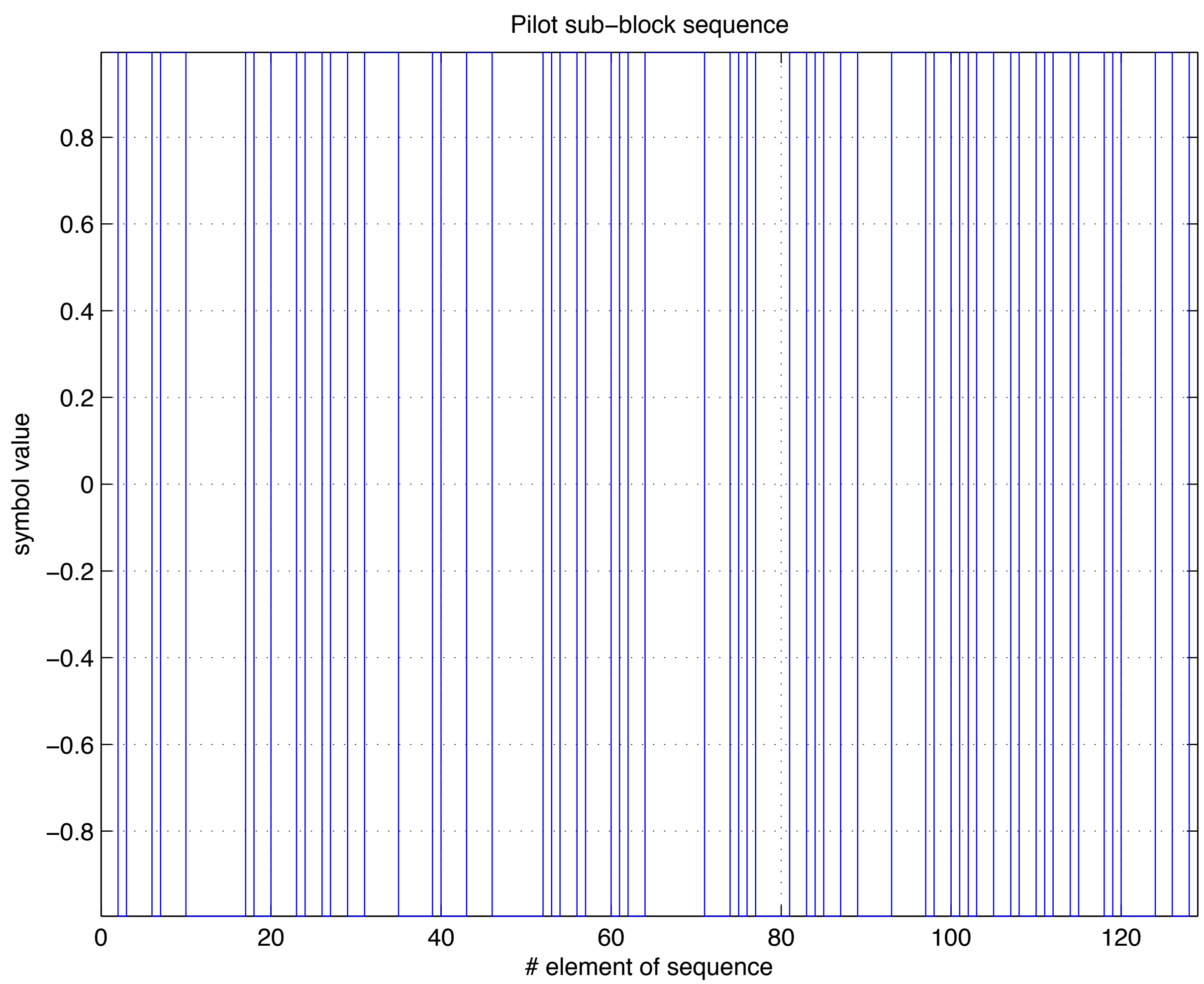


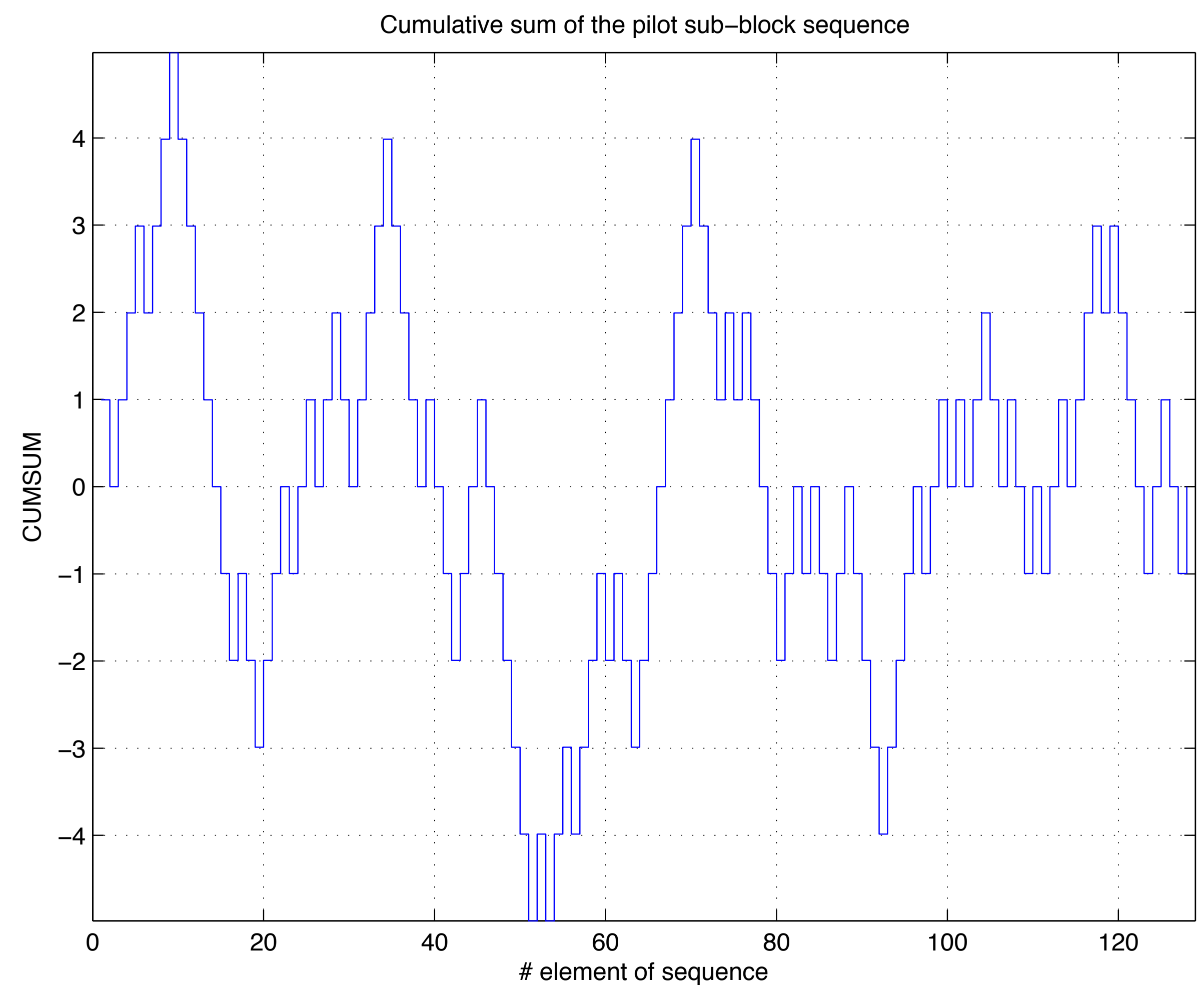
New proposal for S1 and S2 signals

- S1 and S2 pilot sub-blocks with zero sum:
  - Timing recovery and equalizer adaptive algorithms are less affected by base-line wander
  - Better convergence of adaptive filtering algorithms
- S1 and S2 pilot sub-blocks with constrained cumulative sum:
  - Improved behavior of adaptive algorithms because local statistical properties approximates the intended global ones (auto-correlation, mean, probability of each value).
- S2 pilot sub-blocks with minimum cross-correlation among them
- Reduced set of signals for S2, PAM8:
  - Faster convergence and easier design of pilots to fit with zero sum, constrained cumulative sum and minimum cross-correlation
  - PAM8 is still valid for non-linear channel estimation and compensation (theoretically up to 7^{th} order non linear systems)
  - PAM4 was tested in simulation with non-linear channel responses from laboratory and it produce slight performance penalty (0.3 dB). Therefore, PAM8 seems a good tradeoff.

New proposal for S1 and S2 signals

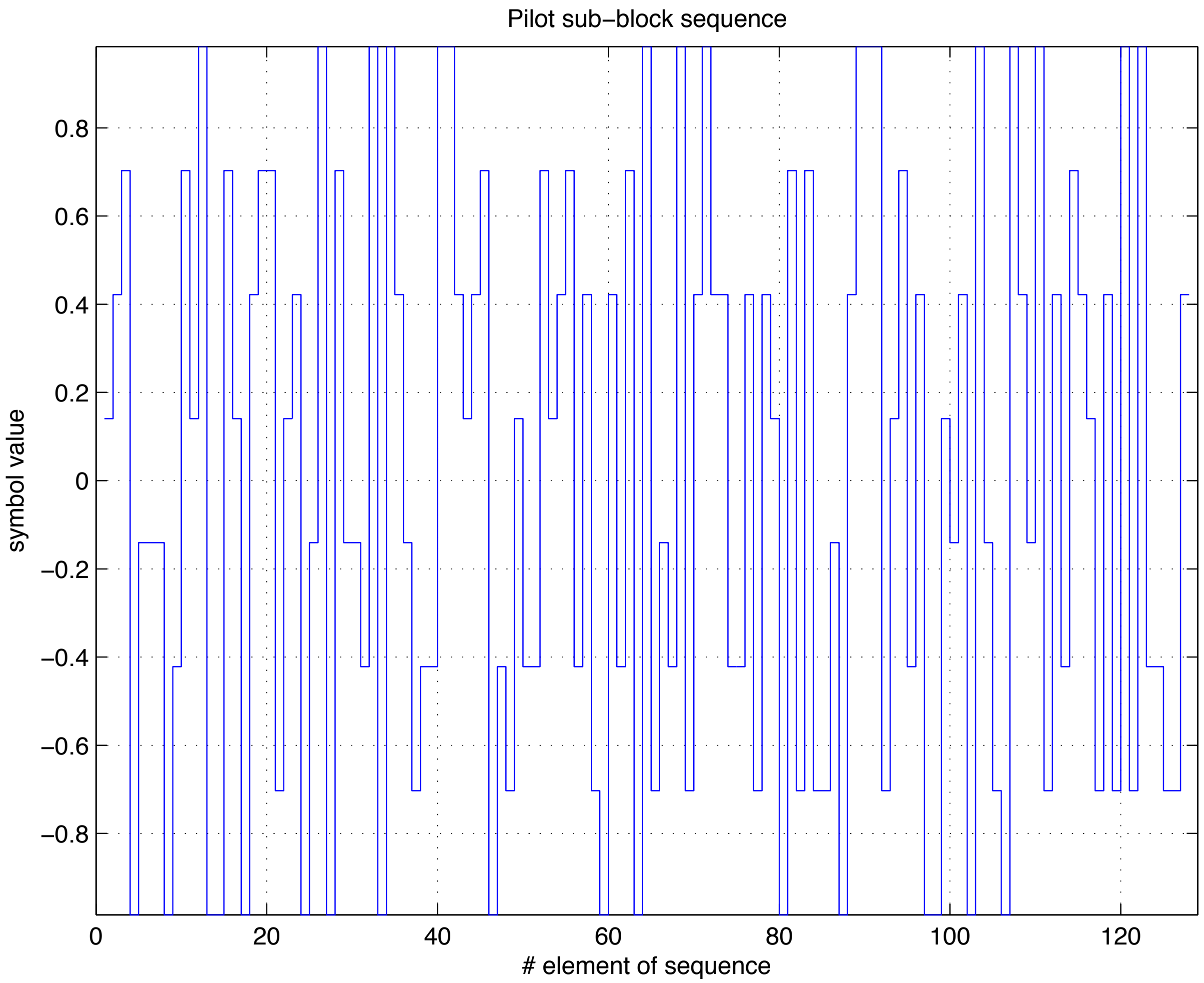
- New S1: sum[x] = 0 , $E[CS_x] = 0$, $std[CS_x] = 2.0$

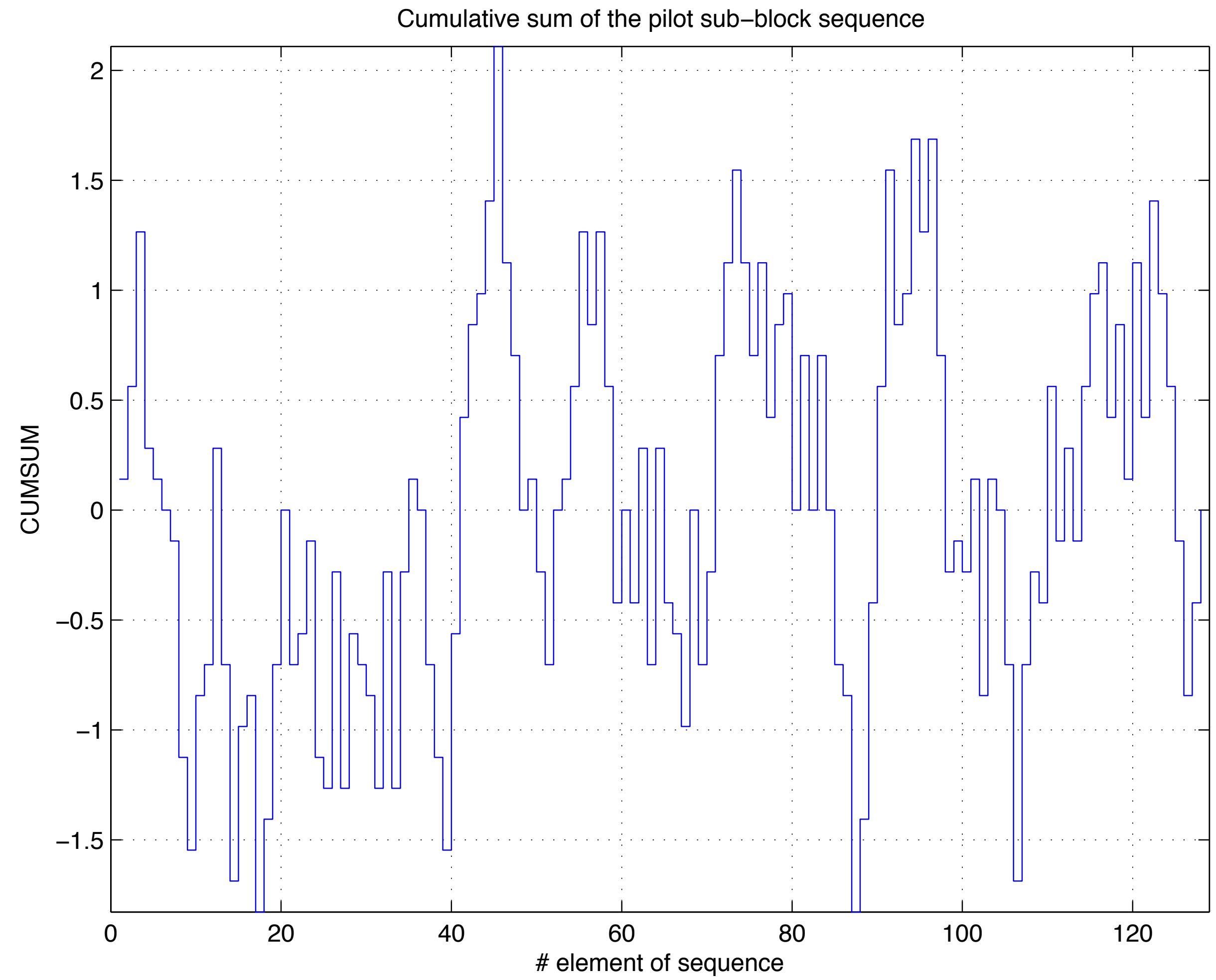




New proposal for S1 and S2 signals

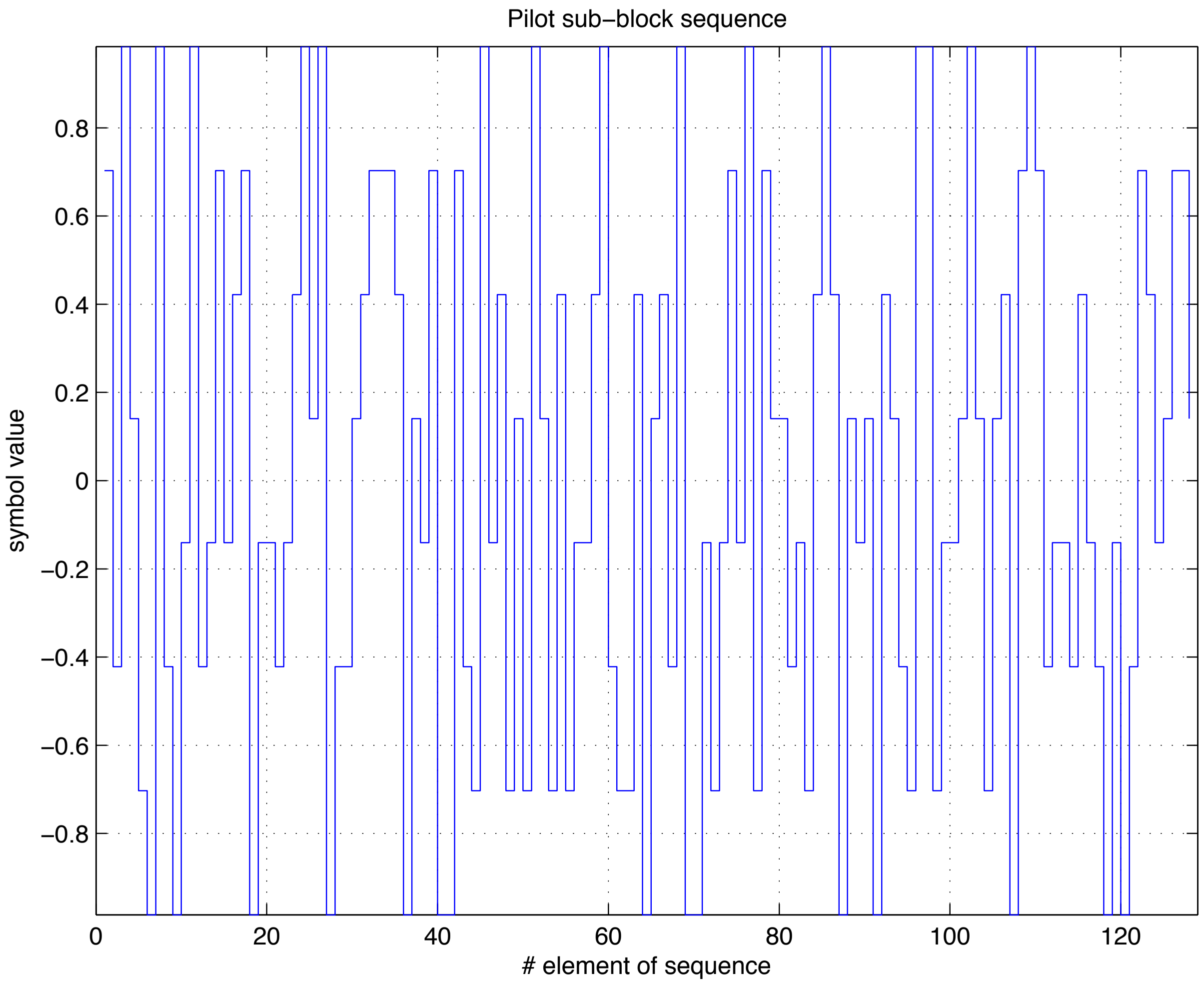
- New $S2_0$: sum[x] = 0 , $E[CS_x] = 0$, $std[CS_x] = 0.86$

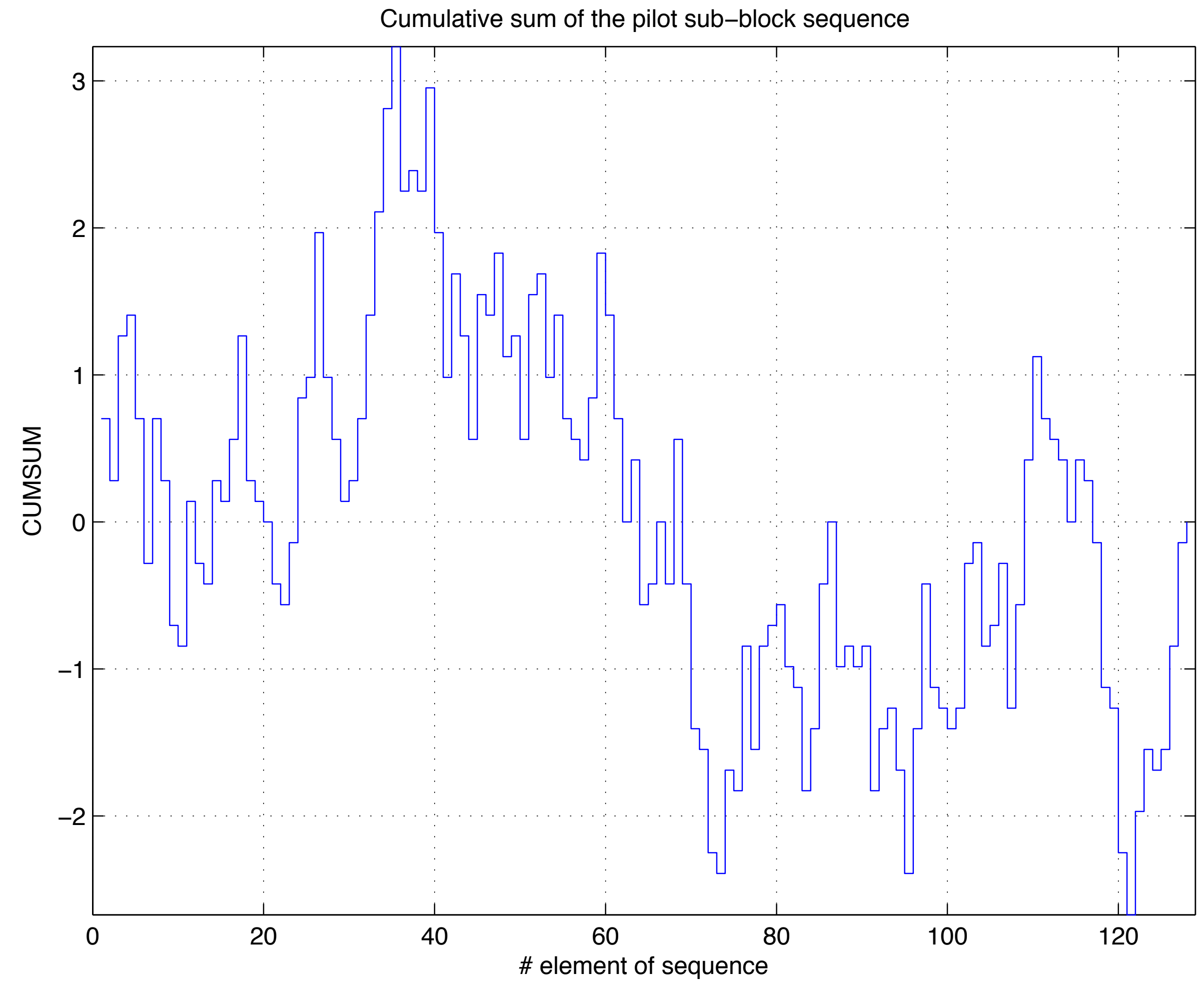




New proposal for S1 and S2 signals

- New $S2_1$: sum[x] = 0 , $E[CS_x] = 0$, $std[CS_x] = 1.25$





New proposal for S1 and S2 signals

- New S1 generation:
  - Same procedure
  - Just change initialization 0xAC2B4B to 0x172DB9D
- New S2 generation:
  - Mapper is changed from PAM256 to PAM8
  - Scaling factor has to modified accordingly
  - The LFSR is initialized as follow previous to generation of each S2 sub-block

$S2_0$	0x945286	$S2_7$	0x50DF4E
$S2_1$	0xF00D43	$S2_8$	0x164252F
$S2_2$	0x1AA60F3	$S2_9$	0x1E587FB
$S2_3$	0xD89E10	$S2_{10}$	0x2CD3AD
$S2_4$	0xDEBAC8	$S2_{11}$	0xEE9512
$S2_5$	0x16913D1	$S2_{12}$	0x1ABFA53
$S2_6$	0x13EACDB		

Questions?