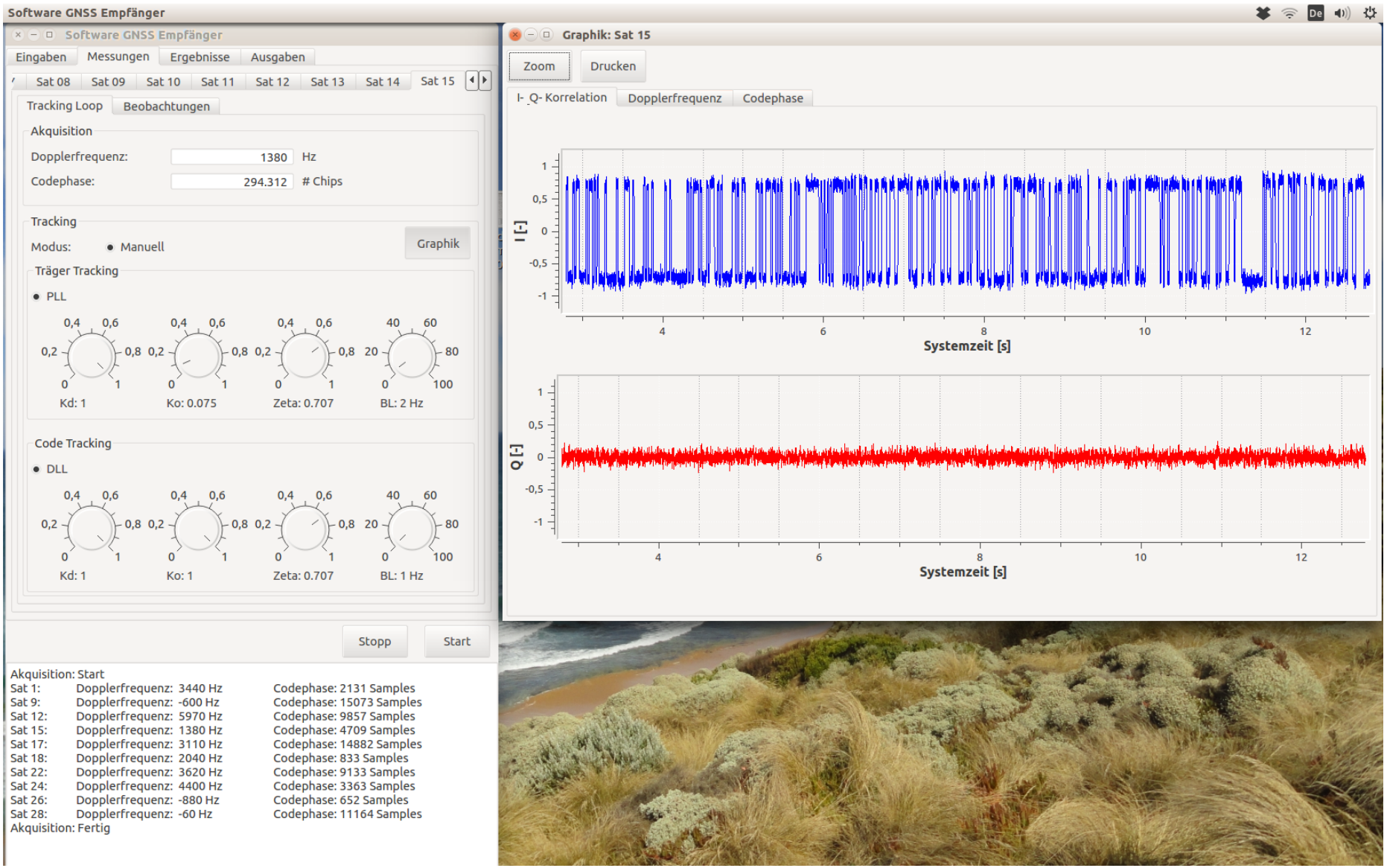
Lab 3: GPS Navigation Message



1. GPS navigation message

Structure:

- Length: 1500 bits
- 5 subframes
  - each subframe has 300 bits (10 words)
  - 1-3 subframes include the ephemeris, clock parameters, ...
  - 4-5 subframes include the almanach, ionospheric parameters, ...

Transfer:

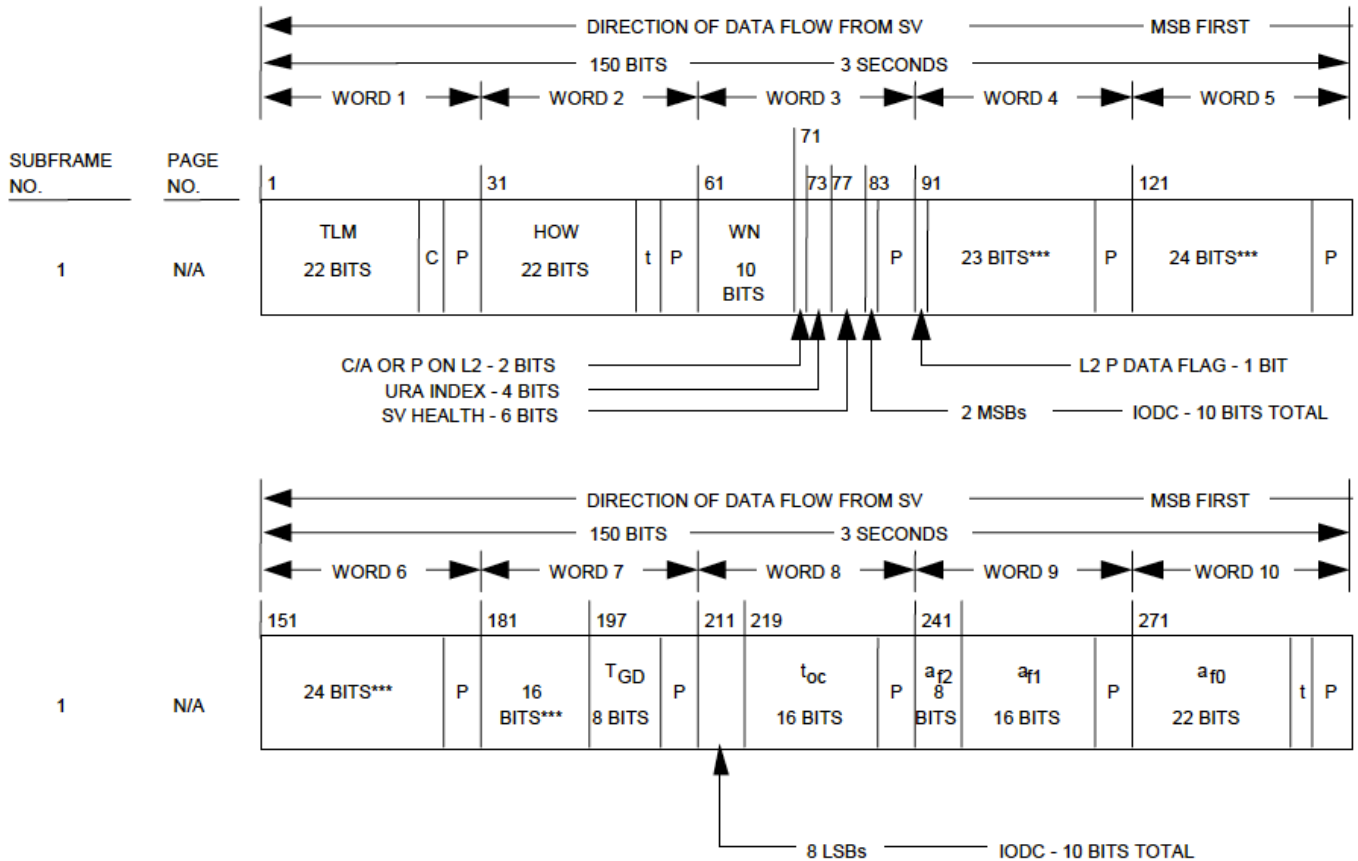
- Bit rate: 50 Hz
- Periods:
  - 30 seconds for a frame
  - 6 seconds for a subframe

Information:

- 1-3 subframes with an update interval of 2 hours
- 4-5 subframes include 25 pages with a repetition rate of 12.5 minutes

1. GPS navigation message

Subframe 1:

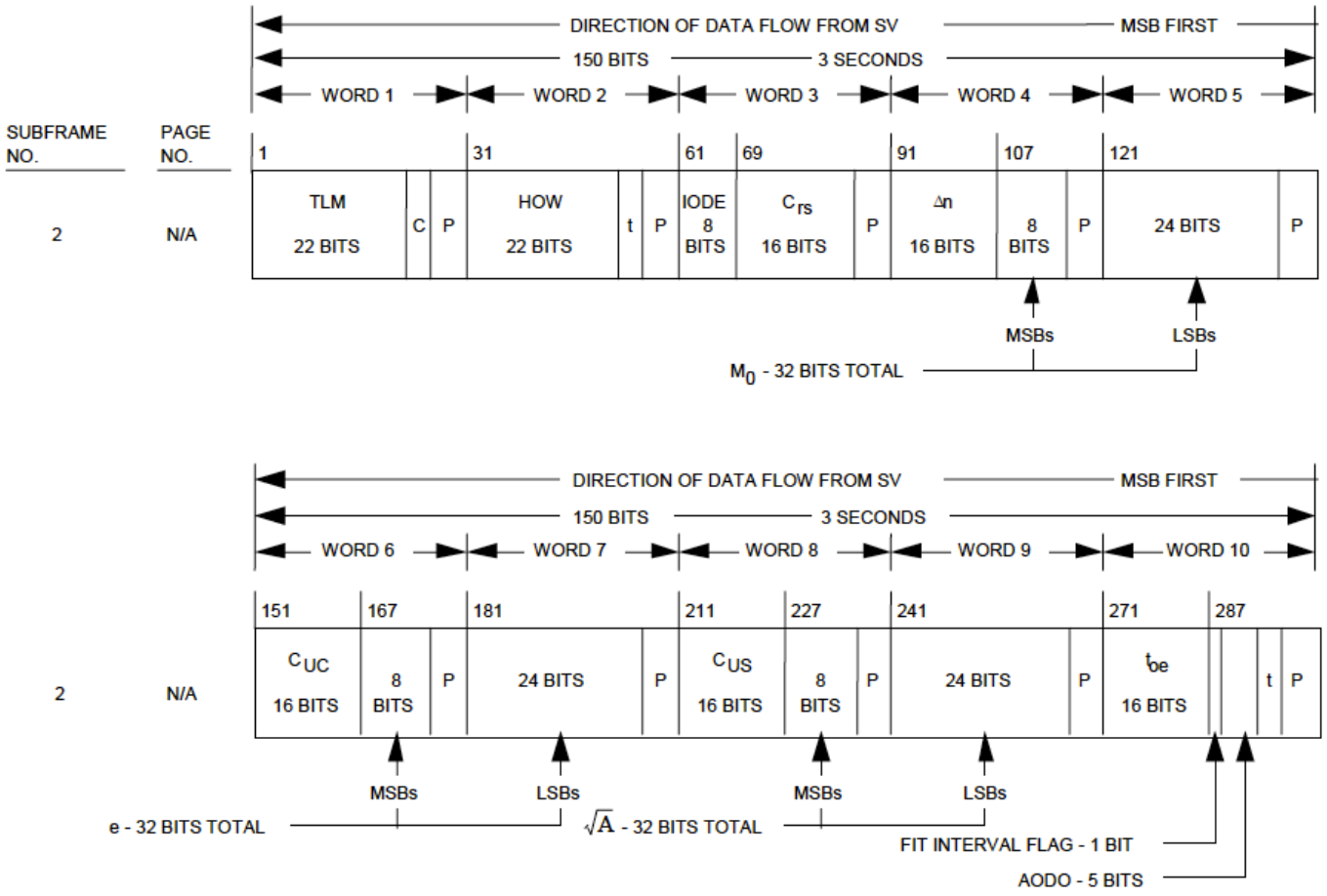


*** RESERVED
P = 6 PARITY BITS
t = 2 NONINFORMATION BEARING BITS USED FOR PARITY COMPUTATION (SEE PARAGRAPH 20.3.5)
C = TLM BITS 23 AND 24. BIT 23 IS THE INTEGRITY STATUS FLAG AND BIT 24 IS RESERVED

[1]

1. GPS navigation message

Subframe 2:



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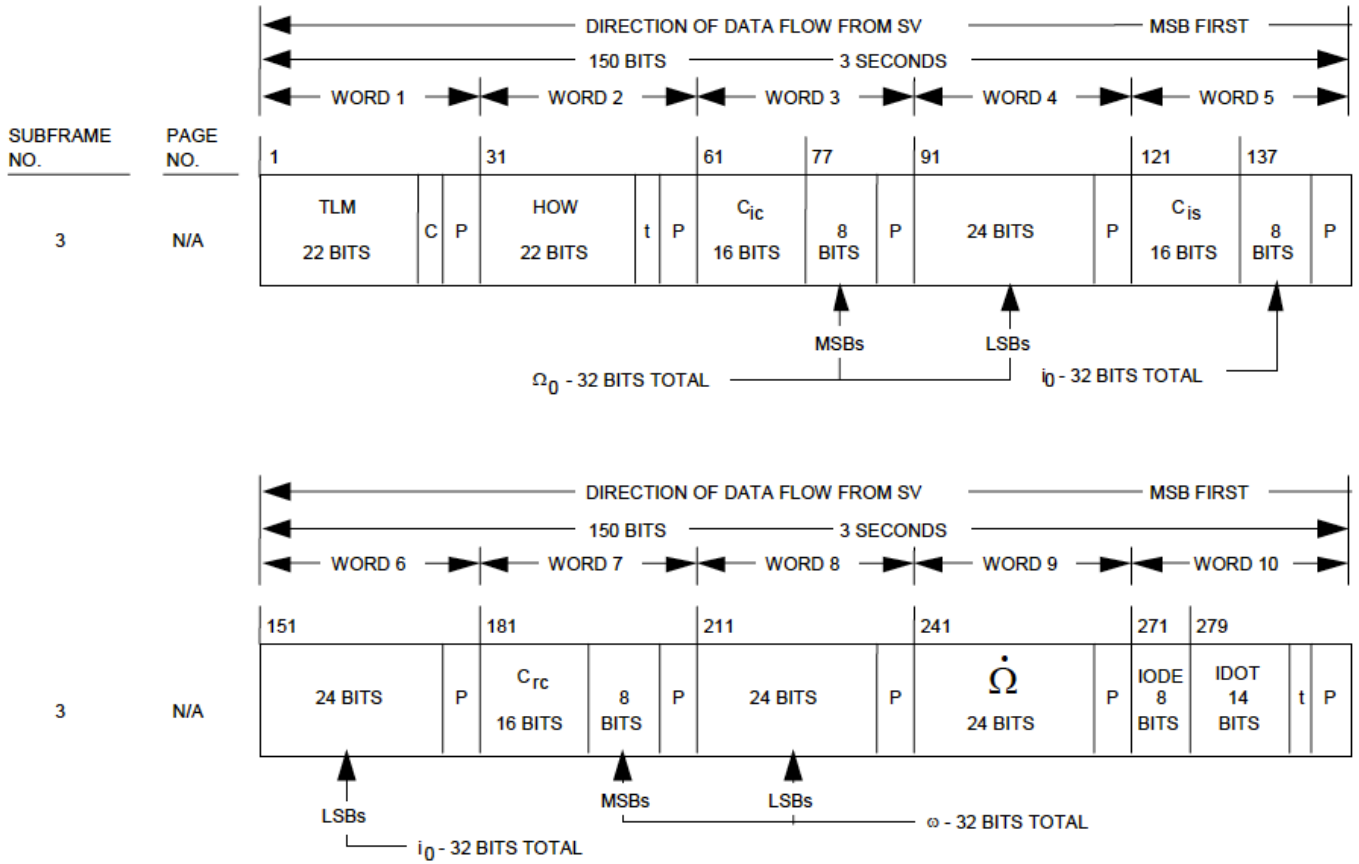
[1]

1. GPS navigation message

Subframe 3:



P = 6 PARITY BITS
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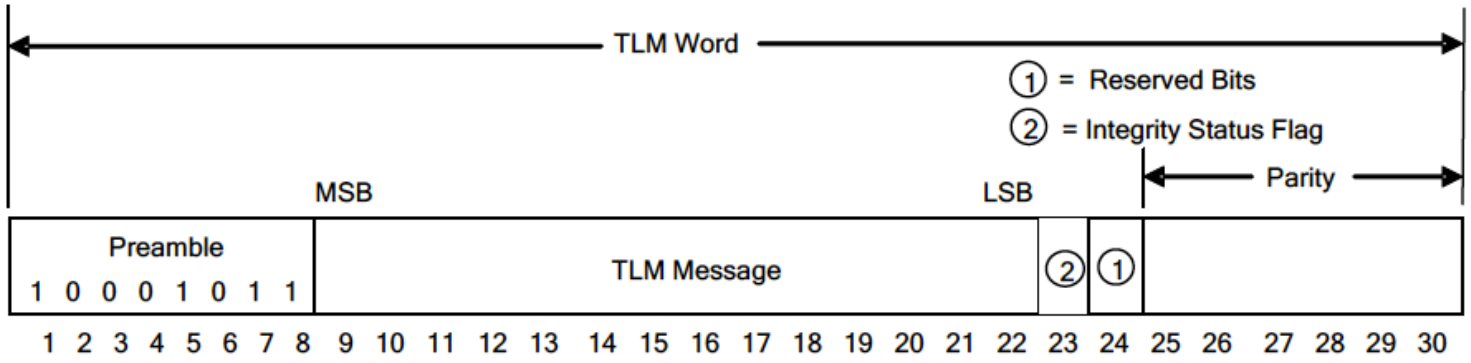
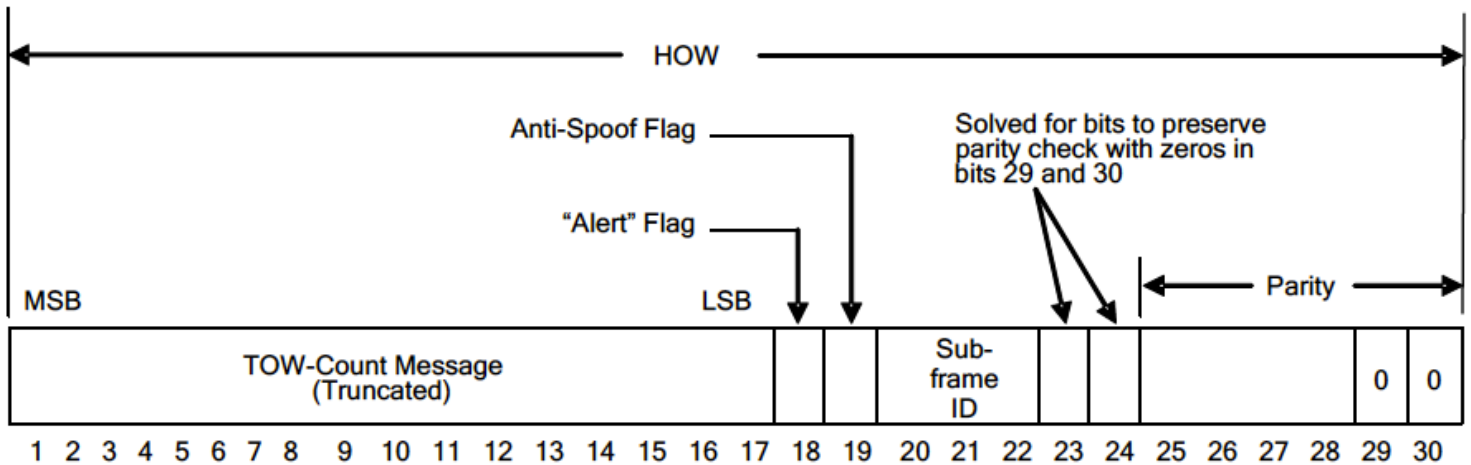
C = TLM BITS 23 AND 24. BIT 23 IS THE INTEGRITY STATUS FLAG AND BIT 24 IS RESERVED

[1]

1. GPS navigation message

TLM and HOW:





[1]

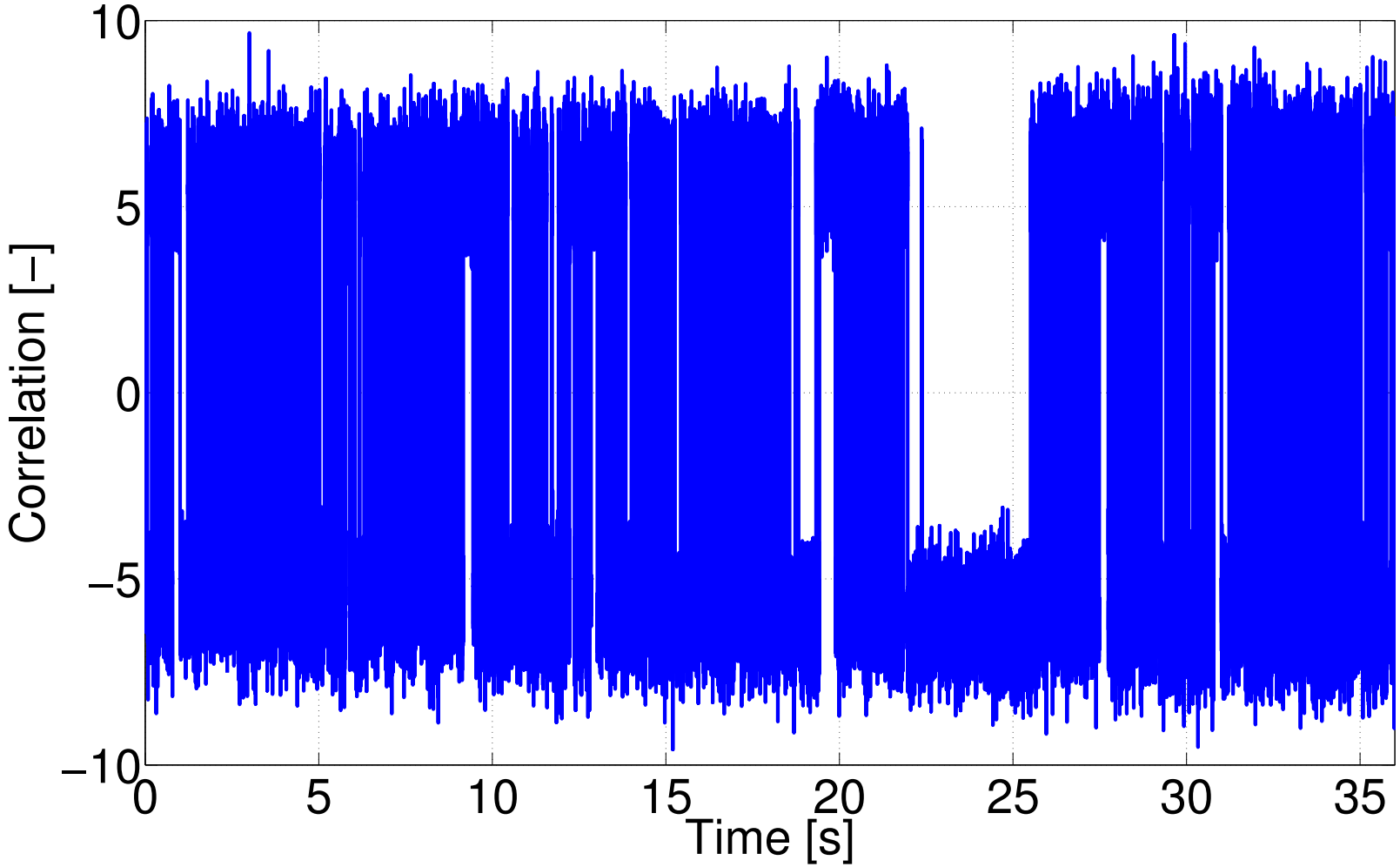
2. Demodulation process

Approach:

1. Saving a time series of I-correlations with a length of 36 seconds
2. Bit detection
3. Subframe detection
4. Performing of "parity check"
5. Reading of the information

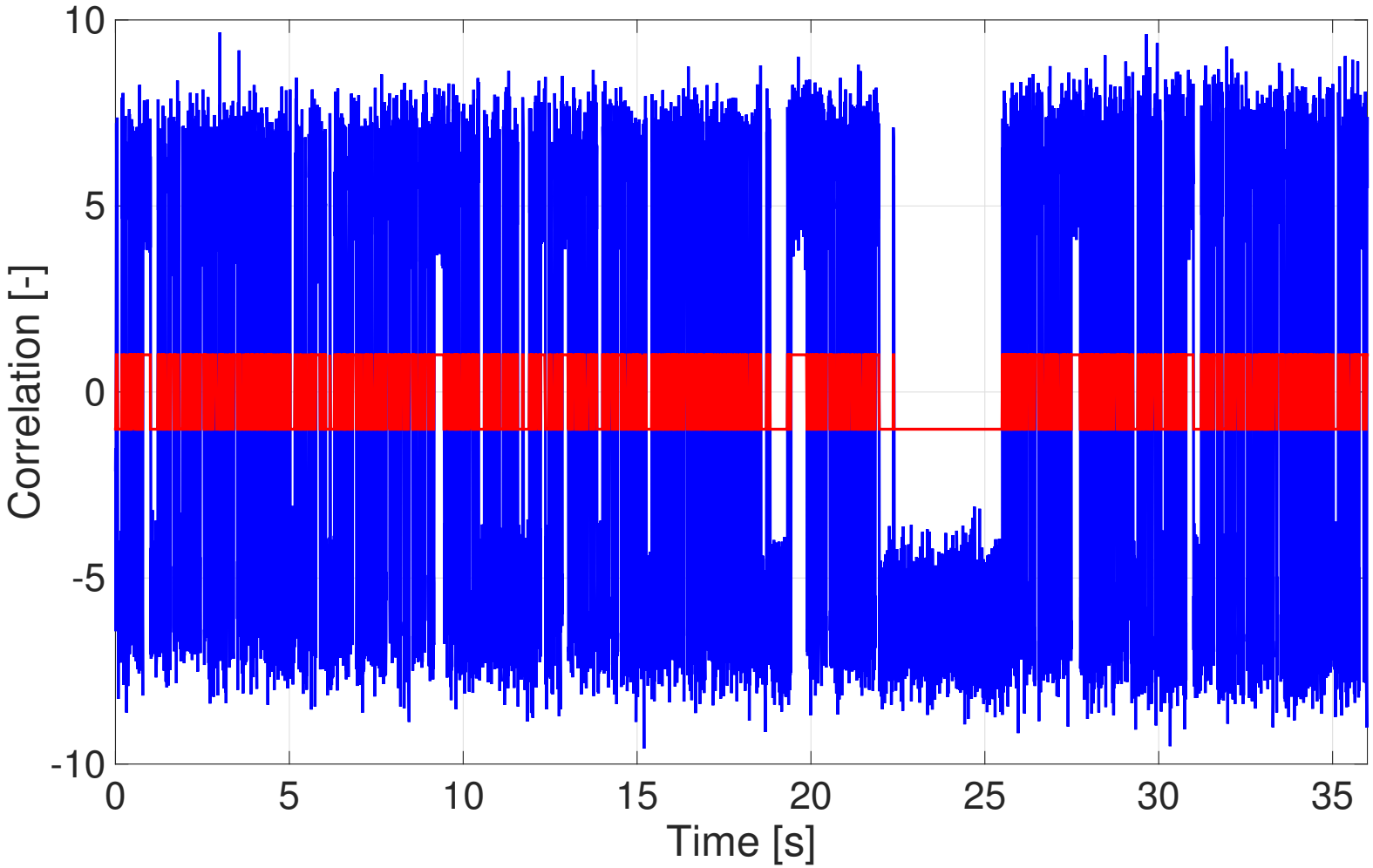
2. Demodulation process

1. Saving a time series of I-correlations with a length of 36 seconds:



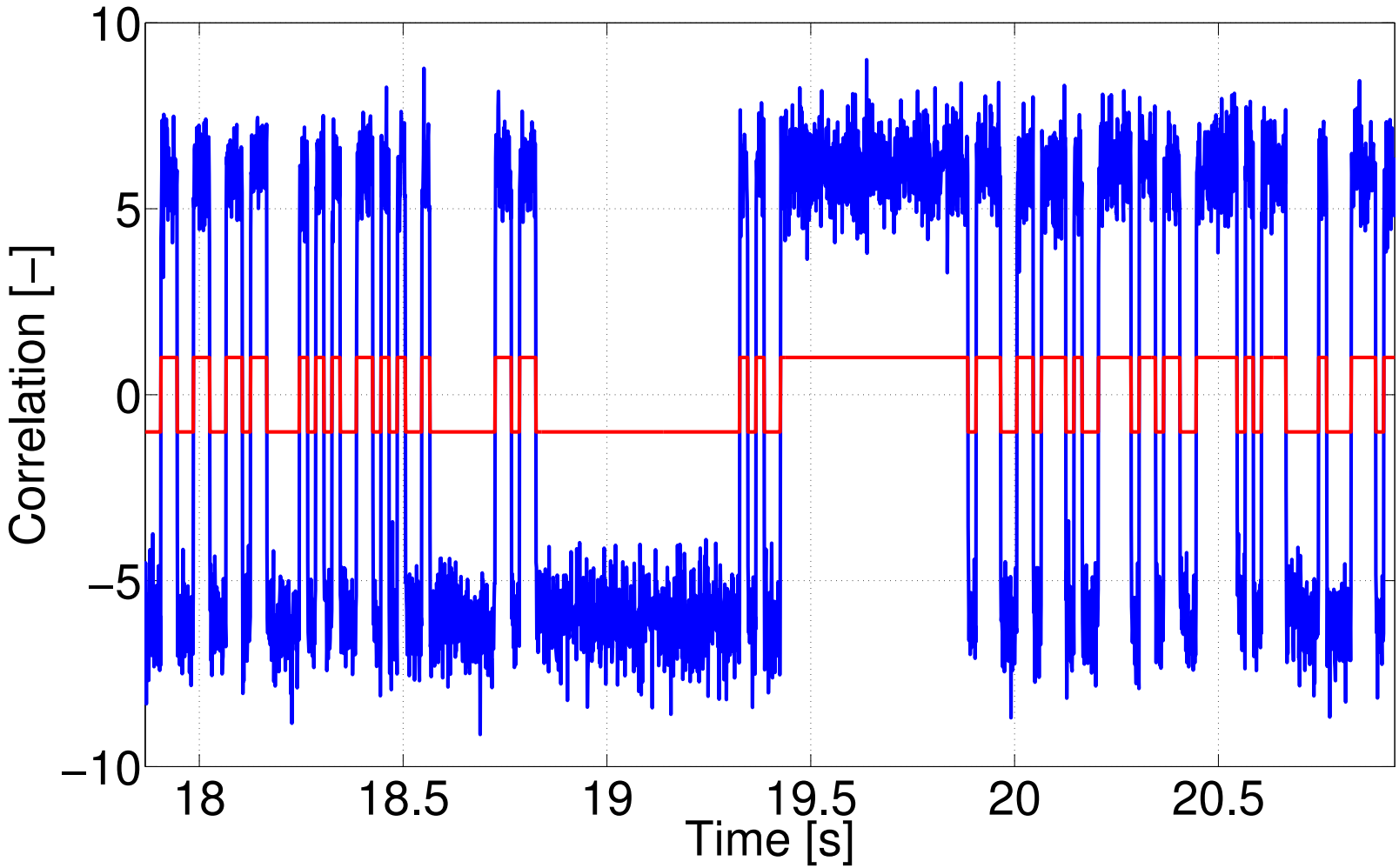
2. Demodulation process

2. Bit detection:



2. Demodulation process

2. Bit detection:



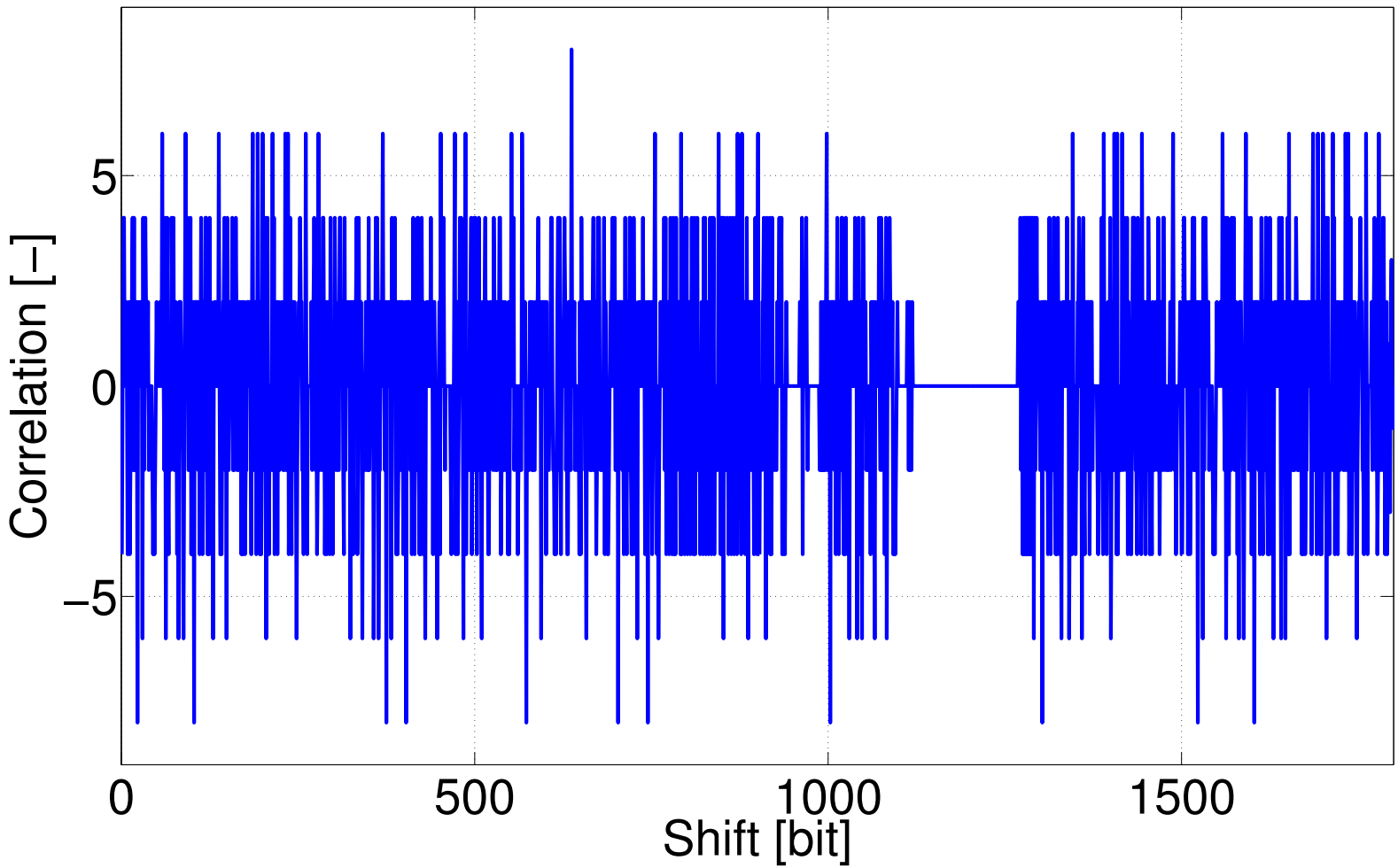
2. Demodulation process

2. Bit detection:
   - Down sampling

3. Subframe detection:
   - Correlation with the preamble
     - Preamble:
       1 0 0 0 1 0 1 1
     - Setting:
       $1 \rightarrow 1$
       $0 \rightarrow$ -1
     - Performing of cross correlation

2. Demodulation process

3. Subframe detection:



2. Demodulation process

4. Performing of "parity check":
   - Operator: “Exclusive-Or (modulo-2 addition) $\oplus$“
     Realisation:

Informatics

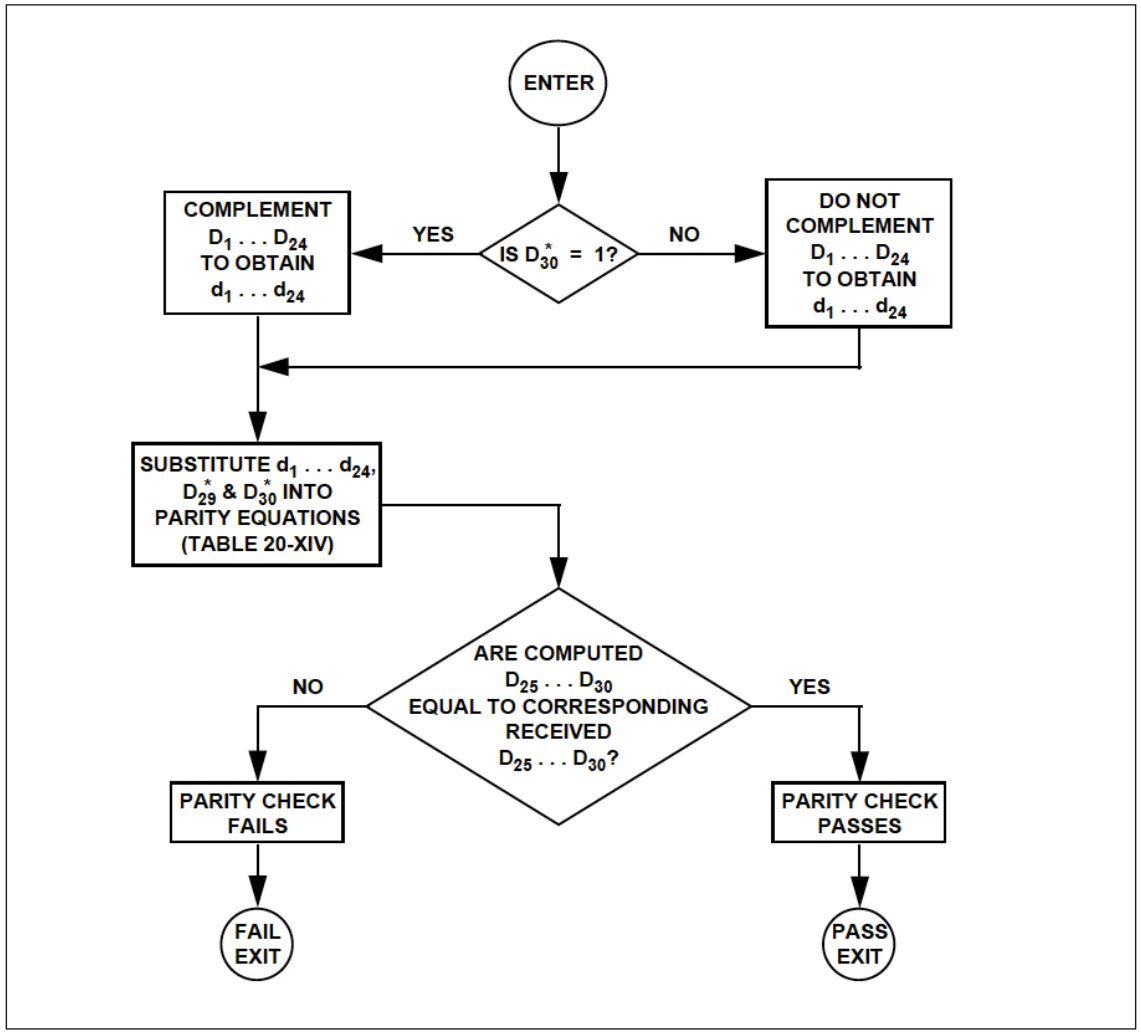
A	**B**	**A xor B**
1	1	0
1	0	1
0	1	1
0	0	0

Mathematics

A	**B**	**A · B**
1	1	1
1	-1	-1
-1	1	-1
-1	-1	1

2. Demodulation process

4. Performing of "parity check":



[1]

2. Demodulation process

4. Performing of "parity check":

Table 20-XIV. Parity Encoding Equations

D_1	=	$d_1 \oplus D_{30}^{\star}$
D_2	=	$d_2 \oplus D_{30}^{\star}$
D_3	=	$d_3 \oplus D_{30}^{\star}$
•		•
•		•
•		•
•		•
D_{24}	=	$d_{24} \oplus D_{30}^{\star}$
D_{25}	=	$D_{29}^{\star} \oplus d_1 \oplus d_2 \oplus d_3 \oplus d_5 \oplus d_6 \oplus d_{10} \oplus d_{11} \oplus d_{12} \oplus d_{13} \oplus d_{14} \oplus d_{17} \oplus d_{18} \oplus d_{20} \oplus d_{23}$
D_{26}	=	$D_{30}^{\star} \oplus d_2 \oplus d_3 \oplus d_4 \oplus d_6 \oplus d_7 \oplus d_{11} \oplus d_{12} \oplus d_{13} \oplus d_{14} \oplus d_{15} \oplus d_{18} \oplus d_{19} \oplus d_{21} \oplus d_{24}$
D_{27}	=	$D_{29}^{\star} \oplus d_1 \oplus d_3 \oplus d_4 \oplus d_5 \oplus d_7 \oplus d_8 \oplus d_{12} \oplus d_{13} \oplus d_{14} \oplus d_{15} \oplus d_{16} \oplus d_{19} \oplus d_{20} \oplus d_{22}$
D_{28}	=	$D_{30}^{\star} \oplus d_2 \oplus d_4 \oplus d_5 \oplus d_6 \oplus d_8 \oplus d_9 \oplus d_{13} \oplus d_{14} \oplus d_{15} \oplus d_{16} \oplus d_{17} \oplus d_{20} \oplus d_{21} \oplus d_{23}$
D_{29}	=	$D_{30}^{\star} \oplus d_1 \oplus d_3 \oplus d_5 \oplus d_6 \oplus d_7 \oplus d_9 \oplus d_{10} \oplus d_{14} \oplus d_{15} \oplus d_{16} \oplus d_{17} \oplus d_{18} \oplus d_{21} \oplus d_{22} \oplus d_{24}$
D_{30}	=	$D_{29}^{\star} \oplus d_3 \oplus d_5 \oplus d_6 \oplus d_8 \oplus d_9 \oplus d_{10} \oplus d_{11} \oplus d_{13} \oplus d_{15} \oplus d_{19} \oplus d_{22} \oplus d_{23} \oplus d_{24}$

Where

$d_1, d_2, \ldots, d_{24}$ are the source data bits;

the symbol $\star$ is used to identify the last 2 bits of the previous word of the subframe;

$D_{25}, D_{26}, \ldots, D_{30}$ are the computed parity bits;

$D_1, D_2, \ldots, D_{29}, D_{30}$ are the bits transmitted by the SV;

$\oplus$ is the "modulo-2" or "exclusive-or" operation.

[1]

2. Demodulation process

5. Reading of the information:

subframe <300x5 double>

<>	1	2	3	4	5
1	1	1	1	1	1
2	0	0	0	0	0
3	0	0	0	0	0
4	0	0	0	0	0
5	1	1	1	1	1
6	0	0	0	0	0
7	1	1	1	1	1
8	1	1	1	1	1
9	0	0	0	0	0
10	0	0	0	0	0
11	0	0	0	0	0
12	0	0	0	0	0
13	1	1	1	1	1
14	0	0	0	0	0
15	0	0	0	0	0
16	1	1	1	1	1
17	0	0	0	0	0

50	0	0	1	1	0
51	1	1	0	0	0
52	0	1	0	1	1
53	1	1	1	1	0
54	1	0	1	0	1
55	0	1	1	0	1
56	1	1	1	0	1
57	1	0	0	0	1
58	1	0	1	1	0
59	0	0	0	0	0
60	0	0	0	0	0
61	0	0	0	0	1

2. Demodulation process

5. Reading of the information:

Determination of the subframe ID:

Subframe	ID Code
1	001
2	010
3	011
4	100
5	101

[1]

2. Demodulation process

5. Reading of the information:

Example:

- Binary reading:

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
1	0	1	1	0	1	0	1

No sign:
$2^7 + 2^5 + 2^4 + 2^2 + 2^0 = 181$

With sign (Two's Complement):
If Bit $8 = 1$ then:
$2^6 + 2^3 + 2^1 = 74$
$-1 \cdot 74 - 1 = -75$
Else:
$2^5 + 2^4 + 2^2 + 2^0 = 53$

2. Demodulation process

5. Reading of the information:

Table 20-III. Ephemeris Parameters

Parameter	No. of Bits**	Scale Factor (LSB)	Effective Range***	Units
IODE	8			(see text)
C_{rs}	16*	2^{-5}		meters
Δn	16*	2^{-43}		semi-circles/sec
M_0	32*	2^{-31}		semi-circles
C_{uc}	16*	2^{-29}		radians
e	32	2^{-33}	0.03	dimensionless
C_{us}	16*	2^{-29}		radians
$\sqrt{A}$	32	2^{-19}		$\sqrt{\text{meters}}$
t_{oe}	16	2^{4}	604,784	seconds
C_{ic}	16*	2^{-29}		radians
Ω_0	32*	2^{-31}		semi-circles
C_{is}	16*	2^{-29}		radians
i_0	32*	2^{-31}		semi-circles
C_{rc}	16*	2^{-5}		meters
ω	32*	2^{-31}		semi-circles
$\dot{\Omega}$	24*	2^{-43}		semi-circles/sec
IDOT	14*	2^{-43}		semi-circles/sec

* Parameters so indicated shall be two's complement, with the sign bit (+ or -) occupying the MSB;
** See Figure 20-1 for complete bit allocation in subframe;
*** Unless otherwise indicated in this column, effective range is the maximum range attainable with indicated bit allocation and scale factor.

[1]

References

[1] IS - GPS 200H
http://www.gps.gov/technical/icwg/#is-gps-200, 11/2015

[2] RINEX 3.01
http://igscb.jpl.nasa.gov/igscb/data/format/rinex301.pdf, 11/2015

[3] Borre, K; et al.
A Software-Defined GPS And GALILEO Receiver, Birkhäuser, 2007