PRE-PROPOSED INTERFACE REVISION NOTICE (PPIRN)

to

ICD-GPS-200C

for

L2 Civil (L2C) Signal

PPIRN-200C-007

31 May 2001

ARINC, Incorporated
2250 E. Imperial Highway, Ste. 450
El Segundo, CA 90245

Description of Change

1. This PPIRN provides information and description of the new proposed civil signal to be transmitted on L2.

2. It should be noted that this new signal is in a proposal and planning phase at this time, and the information and description in this PPIRN does NOT reflect any final GPS JPO official position nor does it reflect accurate and detailed description of the signal which may finally be transmitted. As such, the contents of this PPIRN will be revised whenever needed and appropriate.

3. Any final GPS JPO official position and the official description of the new signal will be formally incorporated into ICD-GPS-200 at a later date via a GPS JPO Configuration Control Board (CCB) authenticated Interface Revision Notice (IRN).

4. The changes are described in this PPIRN using the extracts from ICD-GPS-200C with IRN-200C-001 & IRN-200C-002 & IRN-200C-003 & IRN-200C-004. The changes are described in this PPIRN as follows;

   deletion - strikeout,
   addition - italic.

3. REQUIREMENTS

3.1 Interface Definition. As shown in Figure 3-1, the interface between the GPS Space Segment (SS) and the GPS navigation User Segment (US) consists of two radio frequency (RF) links: L1 and L2. Utilizing these links, the space vehicles (SVs) of the SS shall provide continuous earth coverage for signals which provide to the US the ranging codes and the system data needed to accomplish the GPS navigation (NAV) mission. These signals shall be available to a suitably equipped user with RF visibility to an SV. The related selective availability (SA) and anti-spoofing (A-S) requirements are defined in ICD-GPS-203 and/or in ICD-GPS-224 and/or in ICD-GPS-225 (see note in paragraph 2.1).

3.2 Interface Identification. The carriers of the L-band links are modulated by up to two bit trains, each of which normally is a composite generated by the Modulo-2 addition of a pseudo-random noise (PRN) ranging code and the downlink system data (referred to as NAV data).

3.2.1 Ranging Codes. Three PRN ranging codes are transmitted: the precision (P) code which is the principal NAV ranging code; the Y-code, used in place of the P-code whenever the A-S mode of operation is activated; and the coarse/acquisition (C/A) code which is used primarily for acquisition of the P (or Y) code (denoted as P(Y)). Appropriate code-division-multiplexing techniques allow differentiating between the SVs even though they all transmit at the same L-band frequencies. The SVs will transmit intentionally "incorrect" versions of the C/A and the P(Y) codes where needed to protect the users from receiving and utilizing anomalous NAV signals as a result of a malfunction in the SV's reference frequency generation system. These two "incorrect" codes are termed non-standard C/A (NSC) and non-standard Y (NSY) codes.

For Block IIR-M, IIF, and subsequent blocks of SVs, two additional PRN ranging codes are transmitted. They are the L2 civil-moderate (L2CM) code and the L2 civil-long (L2CL) code. The SVs will transmit intentionally "incorrect" versions of the L2CM and L2CL codes where needed to protect the users from receiving and utilizing anomalous NAV signals as a result of a malfunction in the SV's reference frequency generation system. These "incorrect" codes are termed non-standard L2CM (NSCM) and non-standard L2CL (NSCL) codes.

3.2.1.1 P-Code. The PRN P-code for SV ID number i is a ranging code, $P_i(t)$, of 7 days in length at a chipping rate of 10.23 Mbps. The 7 day sequence is the Modulo-2 sum of two sub-sequences referred to as X1 and $X2_i$; their lengths are 15,345,000 chips and 15,345,037 chips, respectively. The $X2_i$ sequence is an X2 sequence selectively delayed by 1 to 37 chips thereby allowing the basic code generation technique to produce a set of 37 mutually exclusive P-code sequences of 7 days in length. Of these, 32 are designated for use by SVs, while the remaining 5 are reserved for other purposes (e.g. ground transmitters, etc.). Assignment of these code phase segments by SV-ID number (or other use) is given in Table 3-I*A*.

3.2.1.2 Y-code. The PRN Y-code, used in place of the P-code when the A-S mode of operation is activated, is defined in ICD-GPS-203 and/or in ICD-GPS-224 and/or in ICD-GPS-225 (see note in paragraph 2.1).

3.2.1.3 C/A Code. The PRN C/A Code for SV ID number i is a Gold code, $G_i(t)$, of 1 millisecond in length at a chipping rate of 1023 Kbps. The $G_i(t)$ sequence is a linear pattern generated by the Modulo-2 addition of two sub-sequences, G1 and $G2_i$, each of which is a 1023 chip long linear pattern. The epochs of the Gold code are synchronized with the X1 epochs of the P-code. As shown in Table 3-I*A*, the $G2_i$ sequence is a G2 sequence selectively delayed by 5 to 950 chips, thereby generating a set of 36 mutually exclusive C/A-codes. Assignment of these by SV-ID (or other use) is also given in Table 3-I*A*.

3.2.1.4 L2CM Code (IIR-M, IIF, and subsequent blocks). The PRN L2CM-code for SV ID number i is a ranging code, $C_{M,i}(t)$, which is 20 milliseconds in length at a chipping rate of 511.5 Kbps. The epochs of the L2CM code are synchronized with the X1 epochs of the P-code. The $C_{M,i}(t)$ sequence is a linear pattern which is short cycled every period of 10230 chips by resetting with a specified initial state. Assignment of initial states by SV-ID number (or other use) is given in Table 3-IB.

3.2.1.5 L2CL Code (IIR-M, IIF, and subsequent blocks). The PRN L2CL-code for SV ID number i is a ranging code, $C_{L,i}(t)$, which is 1.5 seconds in length at a chipping rate of 511.5 Kbps. The epochs of the L2CL code are synchronized with the X1 epochs of the P-code. The $C_{L,i}(t)$ sequence is a linear pattern which is generated using the same code generator polynomial as the one used for $C_{M,i}(t)$. However, the $C_{L,i}(t)$ sequence is short cycled by resetting with a specified initial state every code period of 767250 chips. Assignment of initial states by SV-ID number (or other use) is also given in Table 3-IB.

3.2.1.~~4~~*6* Non-standard Codes. The NSC, *NSCM*, *NSCL*, and NSY codes, used to protect the user from a malfunction in the SV's reference frequency system (reference paragraph 3.2.1), are not for utilization by the user and, therefore, are not defined in this document.

Table 3-I*A*. Code Phase Assignments (sheet 1 of 2)

SV ID No.	GPS PRN Signal No.	Code Phase Selection		Code Delay Chips		First 10 Chips Octal* C/A	First 12 Chips Octal P
		C/A($G2_i$)	($X2_i$)	C/A	P		
1	1	2 ⊕ 6	1	5	1	1440	4444
2	2	3 ⊕ 7	2	6	2	1620	4000
3	3	4 ⊕ 8	3	7	3	1710	4222
4	4	5 ⊕ 9	4	8	4	1744	4333
5	5	1 ⊕ 9	5	17	5	1133	4377
6	6	2 ⊕ 10	6	18	6	1455	4355
7	7	1 ⊕ 8	7	139	7	1131	4344
8	8	2 ⊕ 9	8	140	8	1454	4340
9	9	3 ⊕ 10	9	141	9	1626	4342
10	10	2 ⊕ 3	10	251	10	1504	4343
11	11	3 ⊕ 4	11	252	11	1642	│
12	12	5 ⊕ 6	12	254	12	1750	│
13	13	6 ⊕ 7	13	255	13	1764	│
14	14	7 ⊕ 8	14	256	14	1772	│
15	15	8 ⊕ 9	15	257	15	1775	│
16	16	9 ⊕ 10	16	258	16	1776	│
17	17	1 ⊕ 4	17	469	17	1156	│
18	18	2 ⊕ 5	18	470	18	1467	│
19	19	3 ⊕ 6	19	471	19	1633	4343

* In the octal notation for the first 10 chips of the C/A code as shown in this column, the first digit (1) represents a "1" for the first chip and the last three digits are the conventional octal representation of the remaining 9 chips. (For example, the first 10 chips of the C/A code for PRN Signal Assembly No. 1 are: 1100100000).

** C/A codes 34 and 37 are common.

*** PRN sequences 33 through 37 are reserved for other uses (e.g. ground transmitters).

⊕ = "exclusive or"

NOTE: The code phase assignments constitute inseparable pairs, each consisting of a specific C/A and a specific P code phase, as shown above.

Table 3-IA. Code Phase Assignments (sheet 2 of 2)							
SV ID No.	GPS PRN Signal No.	Code Phase Selection		Code Delay Chips		First 10 Chips Octal* C/A	First 12 Chips Octal P
		C/A($G2_i$)	($X2_i$)	C/A	P		
20	20	4 ⊕ 7	20	472	20	1715	4343
21	21	5 ⊕ 8	21	473	21	1746	│
22	22	6 ⊕ 9	22	474	22	1763	│
23	23	1 ⊕ 3	23	509	23	1063	│
24	24	4 ⊕ 6	24	512	24	1706	│
25	25	5 ⊕ 7	25	513	25	1743	│
26	26	6 ⊕ 8	26	514	26	1761	│
27	27	7 ⊕ 9	27	515	27	1770	│
28	28	8 ⊕ 10	28	516	28	1774	│
29	29	1 ⊕ 6	29	859	29	1127	│
30	30	2 ⊕ 7	30	860	30	1453	│
31	31	3 ⊕ 8	31	861	31	1625	│
32	32	4 ⊕ 9	32	862	32	1712	│
***	33	5 ⊕ 10	33	863	33	1745	│
***	34**	4 ⊕ 10	34	950	34	1713	│
***	35	1 ⊕ 7	35	947	35	1134	│
***	36	2 ⊕ 8	36	948	36	1456	│
***	37**	4 ⊕ 10	37	950	37	1713	4343

* In the octal notation for the first 10 chips of the C/A code as shown in this column, the first digit (1) represents a "1" for the first chip and the last three digits are the conventional octal representation of the remaining 9 chips. (For example, the first 10 chips of the C/A code for PRN Signal Assembly No. 1 are: 1100100000).

** C/A codes 34 and 37 are common.

*** PRN sequences 33 through 37 are reserved for other uses (e.g. ground transmitters).

⊕ = "exclusive or"

NOTE: The code phase assignments constitute inseparable pairs, each consisting of a specific C/A and a specific P code phase, as shown above.

Table 3-IB. Code Phase Assignments (IIR-M, IIF, and subsequent blocks only) (sheet 1 of 2)

SV ID No.	GPS PRN Signal No.	Initial Shift Register State (Octal)		End Shift Register State (Octal)	
		L2CM	L2CL	L2CM *	L2CL **
1	1	742417664	624145772	552566002	267724236
2	2	756014035	506610362	034445034	167516066
3	3	002747144	220360016	723443711	771756405
4	4	066265724	710406104	511222013	047202624
5	5	601403471	001143345	463055213	052770433
6	6	703232733	053023326	667044524	761743665
7	7	124510070	652521276	652322653	133015726
8	8	617316361	206124777	505703344	610611511
9	9	047541621	015563374	520302775	352150323
10	10	733031046	561522076	244205506	051266046
11	11	713512145	023163525	236174002	305611373
12	12	024437606	117776450	654305531	504676773
13	13	021264003	606516355	435070571	272572634
14	14	230655351	003037343	630431251	731320771
15	15	001314400	046515565	234043417	631326563
16	16	222021506	671511621	535540745	231516360
17	17	540264026	605402220	043056734	030367366
18	18	205521705	002576207	731304103	713543613
19	19	064022144	525163451	412120105	232674654

**   Short cycled period = 10230*
***   Short cycled period = 767250*
****   PRN sequences 33 through 37 are reserved for other uses (e.g. ground transmitters).*

NOTE: There are many other available initial register states which can be used for other signal transmitters including any additional SVs in future.

Table 3-IB. Code Phase Assignments (IIR-M, IIF, and subsequent blocks only) (sheet 2 of 2)

SV ID No.	GPS PRN Signal No.	Initial Shift Register State (Octal)		End Shift Register State (Octal)	
		L2CM	L2CL	L2CM *	L2CL **
20	20	120161274	266527765	365636111	641733155
21	21	044023533	006760703	143324657	730125345
22	22	724744327	501474556	110766462	000316074
23	23	045743577	743747443	602405203	171313614
24	24	741201660	615534726	177735650	001523662
25	25	700274134	763621420	630177560	023457250
26	26	010247261	720727474	653467107	330733254
27	27	713433445	700521043	406576630	625055726
28	28	737324162	222567263	221777100	476524061
29	29	311627434	132765304	773266673	602066031
30	30	710452007	746332245	100010710	012412526
31	31	722462133	102300466	431037132	705144501
32	32	050172213	255231716	624127475	615373171
***	33	500653703	437661701	154624012	041637664
***	34	755077436	717047302	275636742	100107264
***	35	136717361	222614207	644341556	634251723
***	36	756675453	561123307	514260662	257012032
***	37	435506112	240713073	133501670	703702423

* Short cycled period = 10230
** Short cycled period = 767250
*** PRN sequences 33 through 37 are reserved for other uses (e.g. ground transmitters).

NOTE: There are many other available initial register states which can be used for other signal transmitters including any additional SVs in future.

3.2.2 NAV Data. The system data, D(t), includes SV ephemerides, system time, SV clock behavior data, status messages and C/A to P (or Y) code handover information, etc. The 50 bps data is Modulo-2 added to the P(Y)- and C/A- codes; the resultant bit-trains are used to modulate the L1 and L2 carriers. For a given SV, the data train D(t), if present, is common to the P(Y) and C/A codes on both the L1 and L2 channels. The content and characteristics of data ID number 2 are given in Appendix II of this document. Data ID number 1 is no longer in use.

For Block IIR-M, IIF, and subsequent blocks of SVs, L2C Nav data, $D_C(t)$, also includes SV ephemerides, system time, SV clock behavior, status messages, etc. However, $D_C(t)$ is a 25 bps data which is coded in a rate ½ convolutional coder. When selected by ground command, the resulting 50 symbols per second (sps) symbol stream is Modulo-2 added to the L2CM code only; the resultant bit-trains are combined with L2CL code using time-division multiplex method; the combined bit-trains are used to modulate the L2 quadrature-phase carrier. The content and characteristics of data ID number 4 are given in Appendix III of this document.

Block IIR-M SVs have additional capabilities to use, upon ground command, the Nav data, D(t), instead of L2C Nav data, $D_C(t)$, to add to the L2CM code. The Nav data, D(t), can be used in one of two different data rates. D(t) with a data rate of 50 bps can be commanded to be Modulo-2 added to the L2CM code, or D(t) with a data rate of 25 bps can be commanded to be coded in a rate ½ convolutional coder with the resulting 50 sps stream to be Modulo-2 added to the L2CM code.

3.2.3 L-Band Signal Structure. The L1 link consists of two carrier components which are in phase quadrature with each other. Each carrier component is bi-phase shift key (BPSK) modulated by a separate bit train. One bit train is the Modulo-2 sum of the P(Y)-code and NAV data, *D(t),* while the other is the Modulo-2 sum of the C/A-code and the NAV data, *D(t).* The L2 link is BPSK modulated by only one of those two bit trains; the bit train to be used for L2 modulation is selected by ground command. A third modulation mode is also selectable on the L2 channel by ground command: it utilizes the P(Y)-code without the NAV data as the modulating signal. For a particular SV, all transmitted signal elements (carriers, codes and data) are coherently derived from the same on-board frequency source.

For Block IIR-M, IIF, and subsequent blocks of SVs, the L2 consists of two carrier components which are in phase quadrature with each other. One carrier component is BPSK modulated by the bit train which is Modulo-2 sum of the P(Y)-code and Nav data D(t), while the other is BPSK modulated by any one of three other bit trains which are selectable by ground command. The three possible bit trains are; the Modulo-2 sum of the C/A-code and D(t); the C/A-code with no data; and a chip-by-chip time multiplex combination of bit trains consisting of the L2CM code with $D_C(t)$ *and the L2CL code with no data. The L2CM code with the 50 sps symbol stream of* $D_C(t)$ *is time-multiplexed with L2CL code at a 1023 kHz rate.*

For Block IIR-M SVs, there are two additional bit trains from which one can be selected by ground command to be BPSK modulated onto the L2 quadrature-phase carrier. The additional bit trains are; a chip-by-chip time multiplex combination of bit trains consisting of the L2CM code with D(t) at 50 bps and the L2CL code with no data; and a chip-by-chip time multiplex combination of bit trains consisting of the L2CM code with convolution encoded D(t) and L2CL code with no data. The chip-by-chip time multiplex is at a rate of 1023 kHz.

3.3.1.4 Spurious Transmissions. In-band spurious transmissions shall be at least 40 dB below the unmodulated L1 and L2 carriers over the allocated 20.46 MHz channel bandwidth.

3.3.1.5 Phase Quadrature. The two L1 carrier components modulated by the two separate bit trains (C/A-code plus data and P(Y)-code plus data) shall be in phase quadrature (within ±100 milliradians) with the C/A signal carrier lagging the P signal by 90 degrees. Referring to the phase of the P carrier when $P_i(t)$ equals zero as the "zero phase angle", the P(Y)- and C/A-code generator output shall control the respective signal phases in the following manner: when $P_i(t)$ equals one, a 180-degree phase reversal of the P-carrier occurs; when $G_i(t)$ equals one, the C/A carrier advances 90 degrees; when the $G_i(t)$ equals zero, the C/A carrier shall be retarded 90 degrees (such that when $G_i(t)$ changes state, a 180-degree phase reversal of the C/A carrier occurs). The resultant nominal composite transmitted signal phases as a function of the binary state of the modulating signals are as shown in Table 3-II.

For Block IIR-M, IIF, and subsequent blocks of SVs, phase quadrature relationship between the two L2 carrier components shall be the same as for the two L1 carrier components as described above. However, for the L2 case, the civil signal carrier component is modulated by any one of five different bit trains as described in paragraph 3.2.3. The resultant composite transmitted signal phases will vary as a function of the binary state of the modulating signals as well as the signal power ratio

3.3.1.6 User-Received Signal Levels. The SV shall provide L1 and L2 navigation in accordance with the minimum levels specified in Table 3-III into a 3 dB_i linearly polarized user receiving antenna (located near ground) at worst normal orientation, when the SV is above a 5-degree elevation angle. Additional related data is provided as supporting material in paragraph 6.3.1.

Table 3-II. Composite L1 Transmitted Signal Phase		
Nominal Composite L1 Signal Phase*	Code State	
	P	C/A
0° -70.5° +109.5° 180°	0 1 0 1	0 0 1 1
* Relative to 0, 0 code state with positive angles leading and negative angles lagging.		

Table 3-III. Received Minimum RF Signal Strength		
Channel	Signal	
	P(Y)	C/A *(or L2C for Block IIR-M, IIF)*
L1	-163.0 dBW	-160.0 dBW
L2	-166.0 dBW or	-166.0 dBW
L2 (Block IIR-M and IIF)	*-163.5 dBW*	*-163.9 dBW*

3.3.1.9 Signal Polarization The transmitted signal shall be right-hand circularly polarized (RHCP). For the angular range of ±14.3 degrees from boresight, L1 ellipticity shall be no worse than 1.2 dB for Block II/IIA and shall be no worse than 1.8 dB for Block IIR*/IIR-M/IIF* Svs. L2 ellipticity shall be no worse than 3.2 dB for Block II/IIA SVs and shall be no worse than 2.2 dB for Block IIR*/IIR-M/IIF* over the angular range of ±14.3 degrees from boresight.

3.3.2 PRN Code Characteristics. The characteristics of the P-, *L2CM-, L2CL-,* and the C/A-codes are defined below in terms of their structure and the basic method used for generating them. The characteristics of the Y-code are defined in ICD-GPS-203 and/or ICD-GPS-224 and/or ICD-GPS-225 (see note in paragraph 2.1). Figure 3-2 depicts a simplified block diagram of the scheme for generating the 10.23 Mbps $P_i(t)$ and the 1.023 Mbps $G_i(t)$ patterns (referred to as P- and C/A-codes respectively), and for Modulo-2 summing these patterns with the NAV bit train, D(t), which is clocked at 50 bps. The resultant composite bit trains are then used to modulate the L-band carriers.

3.3.2.1 Code Structure. The $P_i(t)$ pattern (P-code) is generated by the Modulo-2 summation of two PRN codes, X1(t) and X2(t - iT), where T is the period of one P-code chip and equals $(1.023 \times 10^7)^{-1}$ seconds, while i is an integer from 1 through 37. This allows the generations of 37 unique P(t) code phases (identified in Table 3-I*A*) using the same basic code generator.

The linear $G_i(t)$ pattern (C/A-code) is the Modulo-2 sum of two 1023-bit linear patterns, G1 and $G2_i$. The latter sequence is selectively delayed by an integer number of chips to produce 36 unique G(t) patterns (defined in Table 3-I*A*).

The $C_{M,i}(t)$ pattern (L2CM-code) is a linear pattern which is reset with a specified initial state every code period of 10230 chips. Different initial states are used to generate different $C_{M,i}(t)$ patterns (defined in Table 3-IB).

The $C_{L,i}(t)$ pattern (L2CL-code) is also a linear pattern but with a longer reset period of 767250 chips. Different initial states are used to generate $C_{L,i}(t)$ and $C_{M,i}(t)$ patterns for a given SV-ID (defined in Table 3-IB).

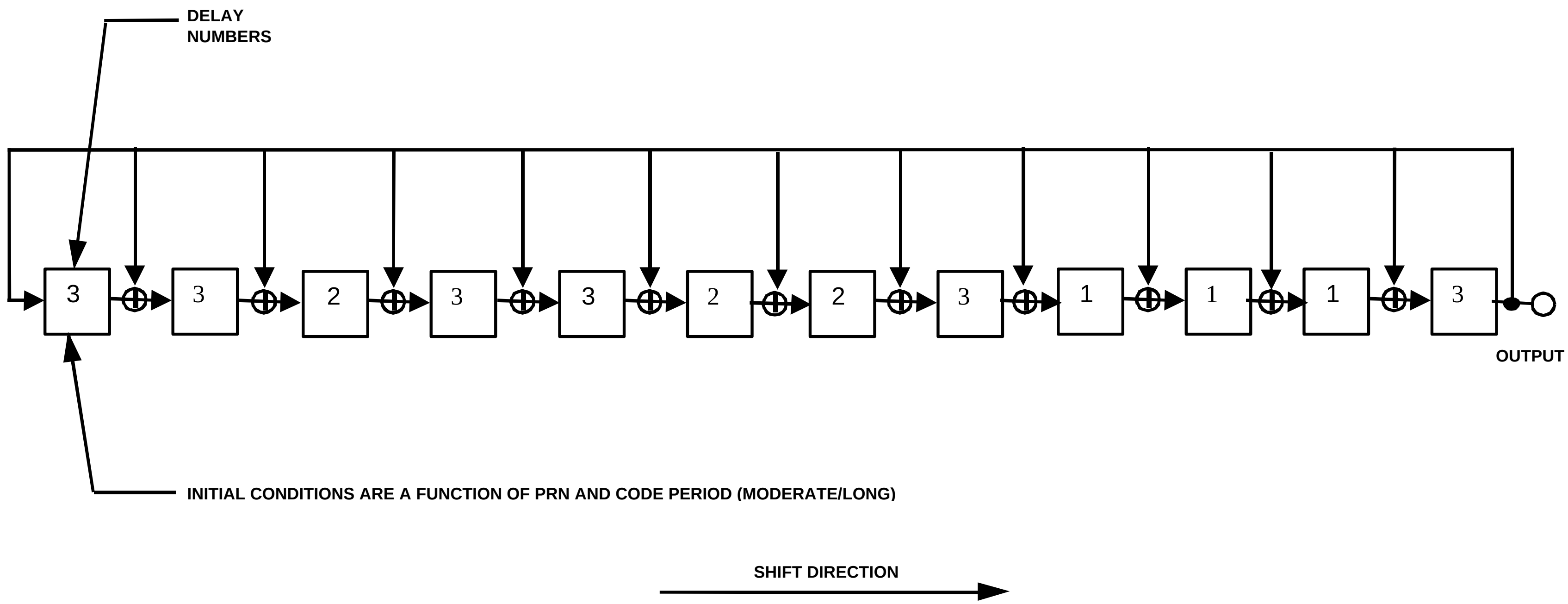
3.3.2.2 P-Code Generation. Each $P_i(t)$ pattern is the Modulo-2 sum of two extended patterns clocked at 10.23 Mbps (X1 and $X2_i$). X1 itself is generated by the Modulo-2 sum of the output of two 12-stage registers (X1A and X1B) short cycled to 4092 and 4093 chips respectively. When the X1A short cycles are counted to 3750, the X1 epoch is generated. The X1 epoch occurs every 1.5 seconds after 15,345,000 chips of the X1 pattern have been generated. The polynomials for X1A and X1B, as referenced to the shift register input, are:

X1A: $1 + X^6 + X^8 + X^{11} + X^{12}$, and

X1B: $1 + X^1 + X^2 + X^5 + X^8 + X^9 + X^{10} + X^{11} + X^{12}$.

Samples of the relationship between shift register taps and the exponents of the corresponding polynomial, referenced to the shift register input, are as shown in Figures 3-3, 3-4, 3-5 and 3-6.

3.3.2.4 <u>L2CM-/L2CL-Code Generation</u>. Each $C_{M,i}(t)$ pattern (L2CM-code) and $C_{L,i}(t)$ pattern (L2CL-code) are generated using the same code generator polynomial each clocked at 511.5 Kbps. Each pattern is initiated and reset with a specified initial state (defined in Table 3-IB). $C_{M,i}(t)$ pattern is reset after 10230 chips resulting in a code period of 20 milliseconds, and $C_{L,i}(t)$ pattern is reset after 767250 chips resulting in a code period of 1.5 seconds. The L2CM and L2CL shift registers are initialized at the P-coder X1 epoch. The maximal polynomial used for L2CM and L2CL codes is 1112225171 (octal) of degree 27. The L2CM and L2CL code generator is conceptually described in Figure 3-14 using modular-type shift register generator.



3-14 L2CM/L2CL Shift Register Generator Configuration

3.3.3 Navigation Data. The content and format of the NAV data for data ID number*s* 2 *and 4* are given in Appendi~~x~~*ces* II *and III, respectively,* of this document (reference paragraph 20.3.3.5.1.1). Data ID number 1 is no longer in use.

3.3.3.1 Navigation Data Modulation. The L2C Nav bit train, $D_C(t)$, is rate ½ encoded and, thus, clocked at 50 sps. The resultant symbol sequence is then Modulo-2 added to the L2CM-code. Upon ground command, the Nav bit train, D(t), can also be rate ½ encoded and be used to modulate the L2CM-code instead of using $D_C(t)$. However, the data rate of D(t) for this purpose will be 25 bps resulting in 50 sps.

3.3.3.1.1 Forward Error Correction. The L2C NAV bit train, $D_C(t)$, will always be rate 1/2 convolutional encoded with a Forward Error Correction (FEC) code. The Nav bit train, D(t), can be selected to be convolution encoded. The resulting symbol rate is 50 sps. The convolutional coding will be constraint length 7, with a convolutional encoder logic arrangement as illustrated in Figure 3-15. The G1 symbol is selected on the output as the first half of a 40-millisecond data bit period.

Twelve-second navigation messages broadcast by the SV are synchronized with every eighth of the SV's P(Y) code X1 epochs.

Because the FEC encoding convolves successive messages, it is necessary to define which transmitted symbol is synchronized to SV time, as follows. The beginning of the first symbol that contains any information about the first bit of a message will be synchronized to every eighth X1 epoch. The users' convolutional decoders will introduce a fixed delay that depends on their respective algorithms (usually 5 constraint lengths, or 35 bits), for which they must compensate to determine system time from the received signal. This convolutional decoding delay and the various relationships with the start of the data block transmission and SV time are illustrated in Figure 3-16.

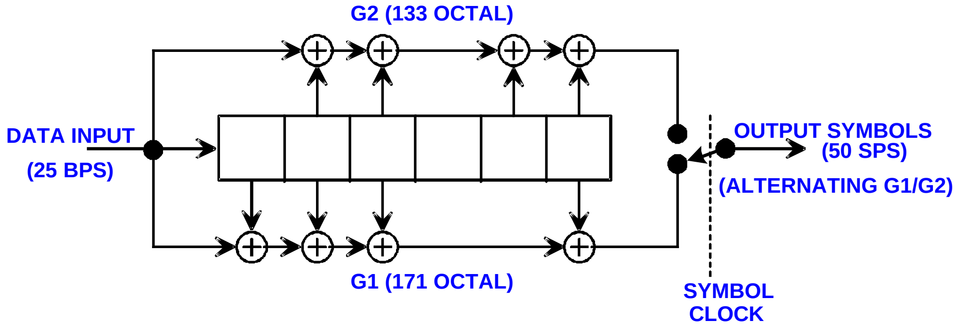


Figure 3-15. Convolutional Encoder

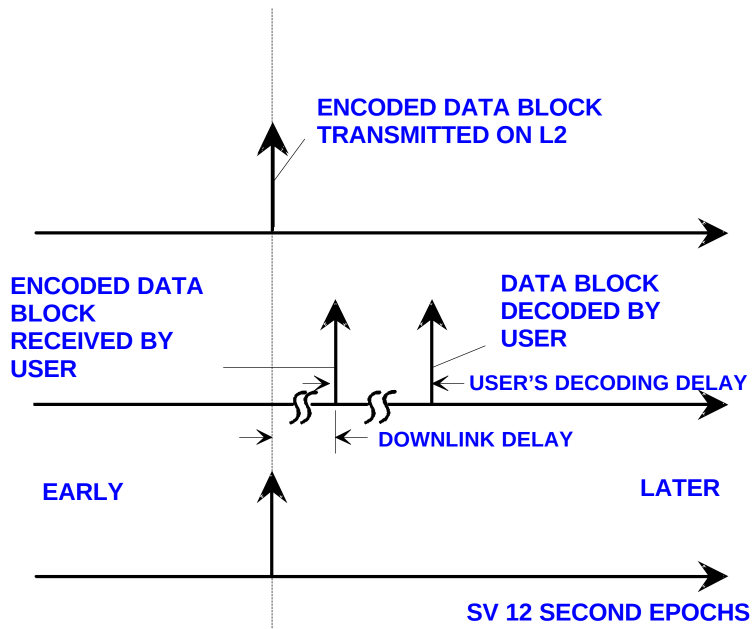


Figure 3-16. Convolutional Transmit/Decoding Timing Relationships

30. APPENDIX III. GPS NAVIGATION DATA STRUCTURE FOR DATA ID NO. 4

30.1 Scope. This appendix describes the specific GPS navigation (NAV) data structure denoted by data ID number 4. This data ID number, when transmitted as part of the NAV data, shall be represented by the two-bit binary notation as 11.

30.2 Applicable Documents.

30.2.1 Government Documents. In addition to the documents listed in paragraph 2.1, the following documents of the issue specified contribute to the definition of the NAV data related interfaces and form a part of this Appendix to the extent specified herein.

Specifications

None

Standards

None

Other Publications

None

30.2.2 Non-Government Documents. In addition to the documents listed in paragraph 2.2, the following documents of the issue specified contribute to the definition of the NAV data related interfaces and form a part of this Appendix to the extent specified herein.

Specifications

None

Other Publications

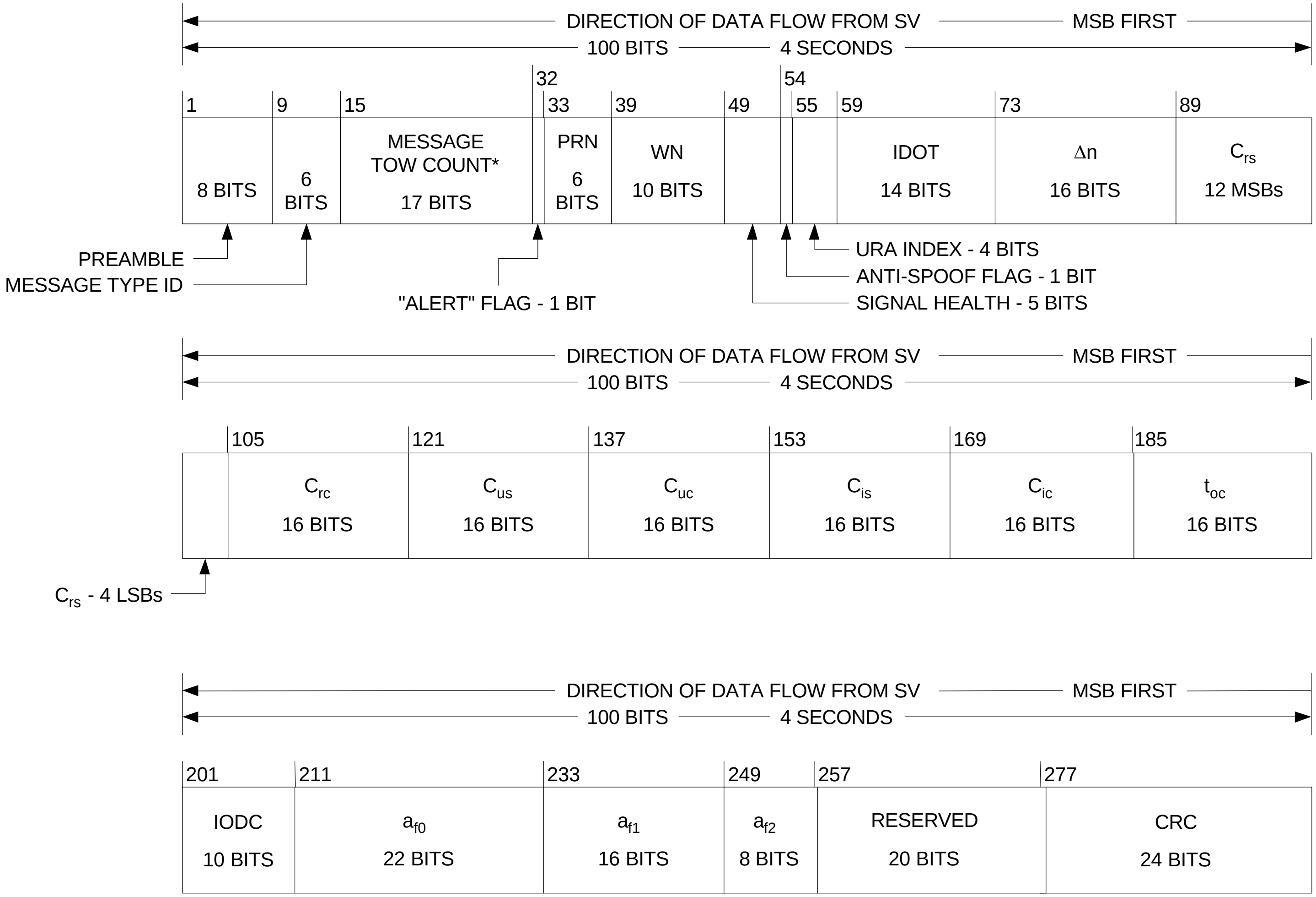
none

30.3 Requirements

30.3.1 Data Characteristics. The L2CM channel data stream mostly contains the same data as the L1 and L2 C/A data stream, but in an entirely different format. Also, the L2CM data stream uses a different parity algorithm.

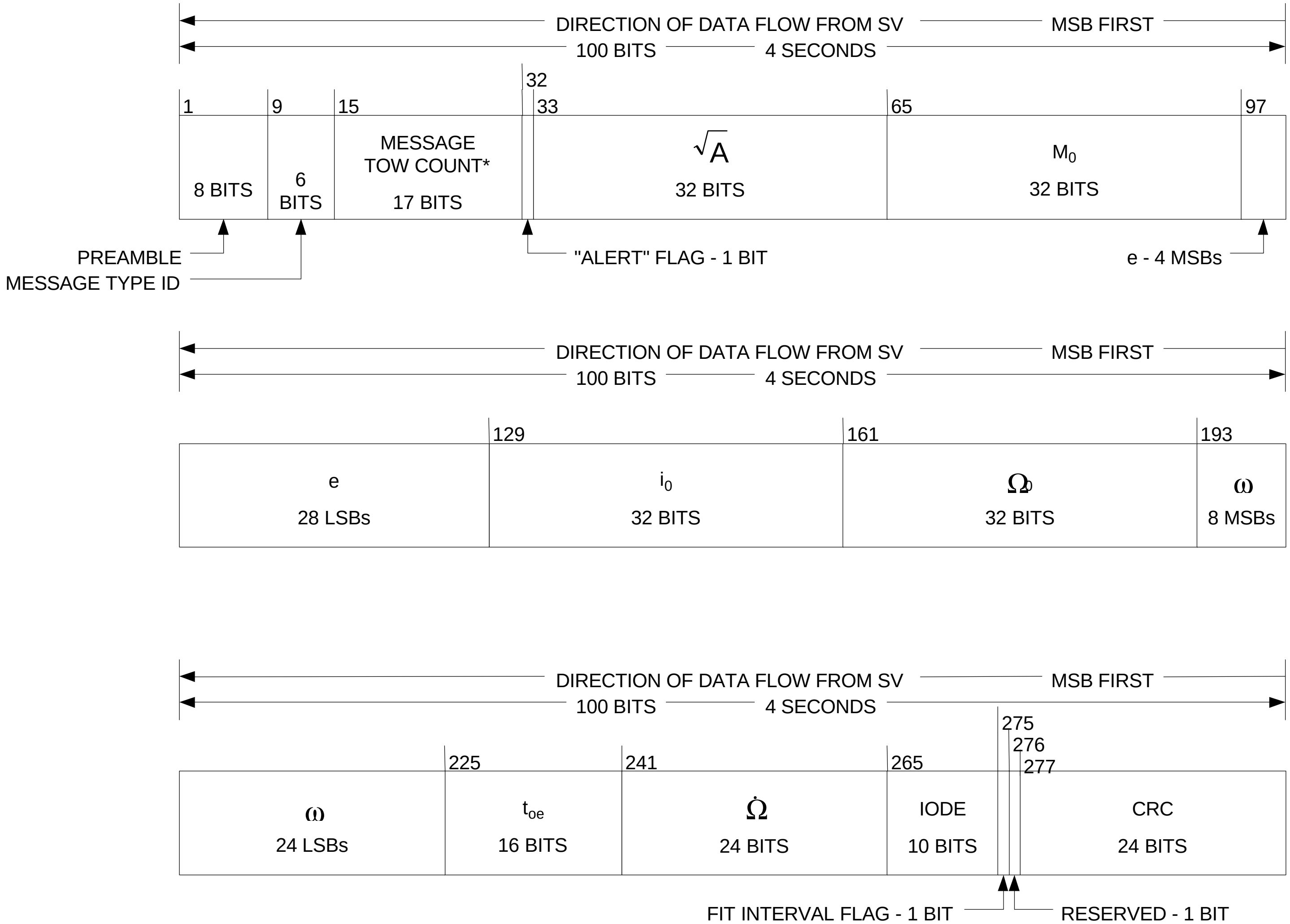
30.3.2 Message Structure. As shown in Figures 30-1 through 30-5, the L2CM message structure utilizes a basic format of twelve-second 300-bit long messages. Each message contains a CRC parity block consisting of 24 bits covering the entire twelve-second message (300 bits) (reference Section 30.3.5). At present, only message types 1-6 are defined. Message types 7 through 64 are reserved.

30.3.3 Message Content. Each message starts with an 8-bit preamble – 10001011, followed by a 6-bit message type ID and the 17-bit message time of week (TOW) count. When the value of the message TOW count is multiplied by 6, it represents SV time in seconds at the start of the next 12-second message. An "alert" flag, when raised (bit 32 = "1"), indicates to the user that the SV URA may be worse than indicated in Message Type 1, and the SV should be used at the user's own risk. A 6-bit PRN number of the transmitting SV, with a range of 1 to 37, starts at bit 33 of Message Types 1, 3, 4, 5 and 6.



* MESSAGE TOW COUNT = 17 MSBs OF ACTUAL TOW COUNT AT START OF NEXT 12-SECOND MESSAGE

Figure 30-1. Message Type 1 Format



* MESSAGE TOW COUNT = 17 MSBs OF ACTUAL TOW COUNT AT START OF NEXT 12-SECOND MESSAGE

Figure 30-2. Message Type 2 Format

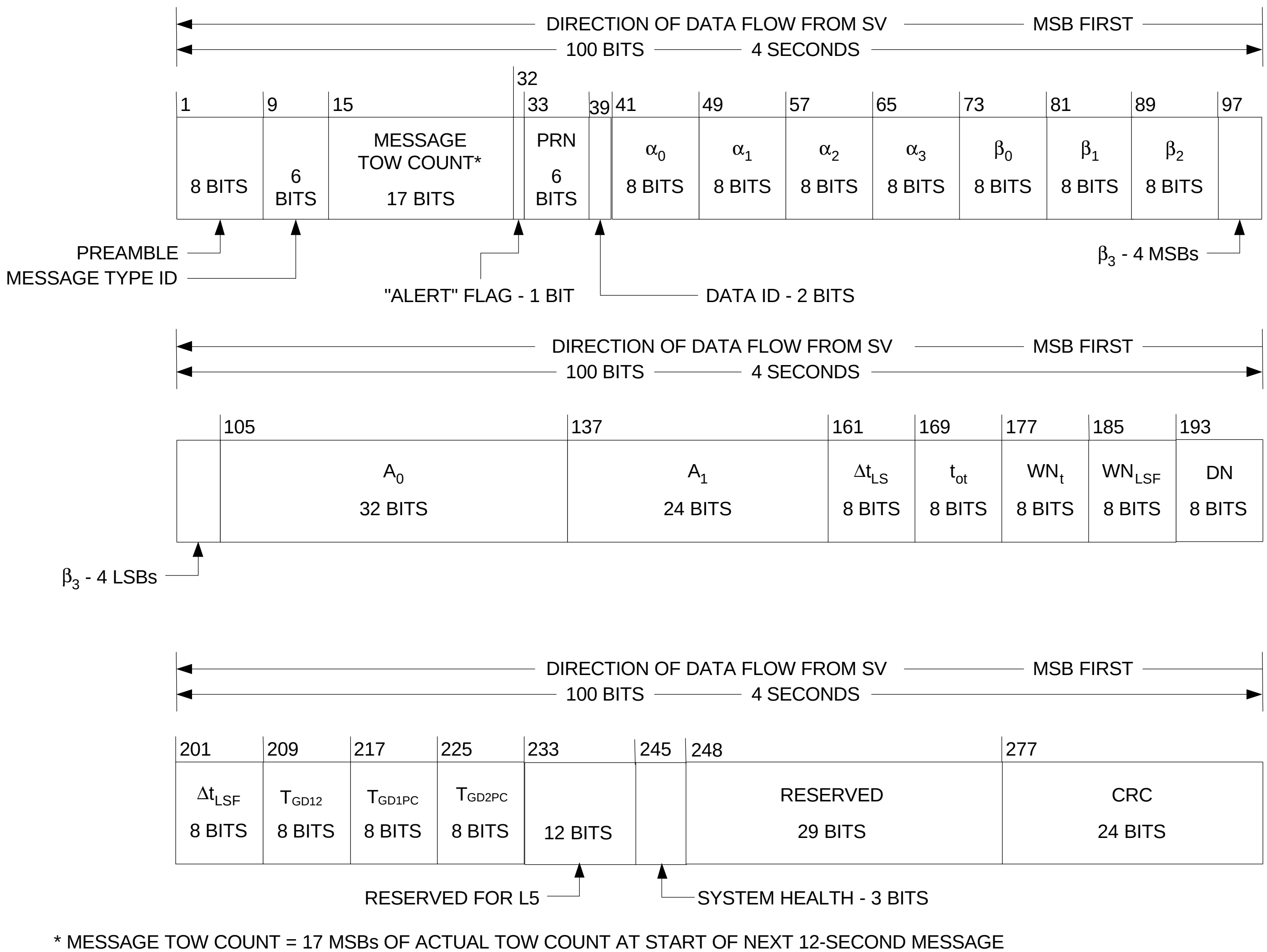


Figure 30-3. Message Type 3 Format

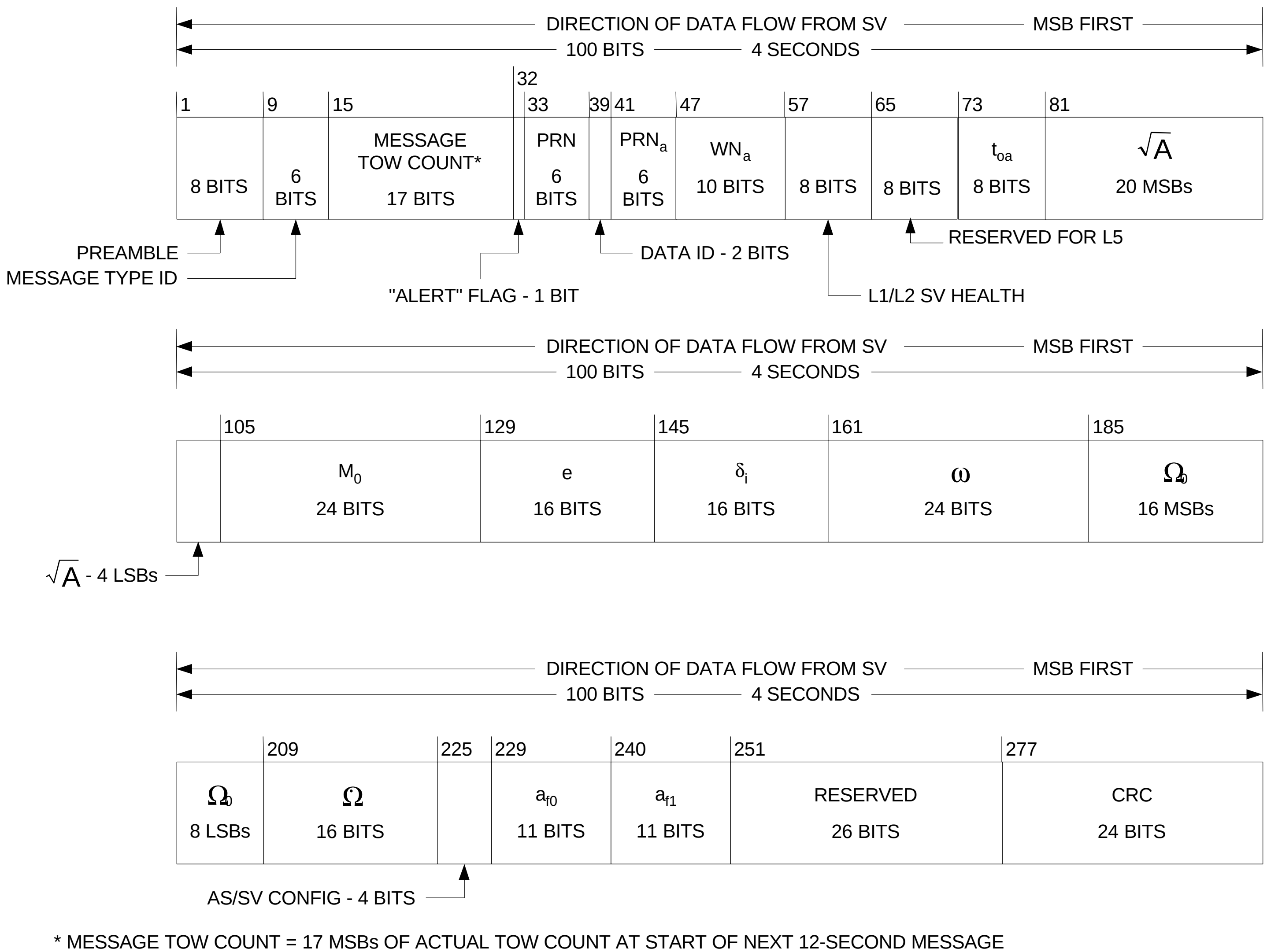


Figure 30-4. Message Type 4 Format

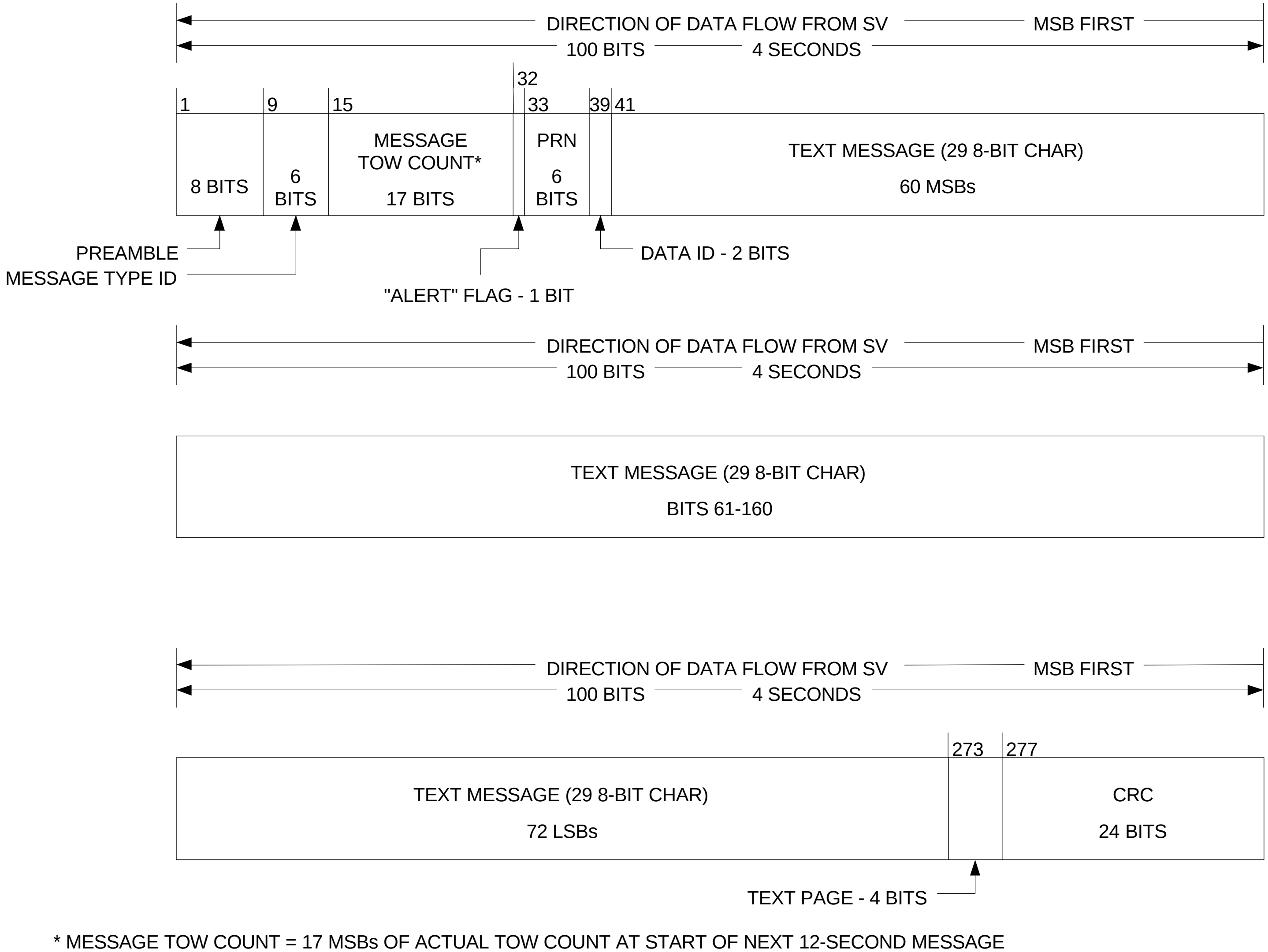
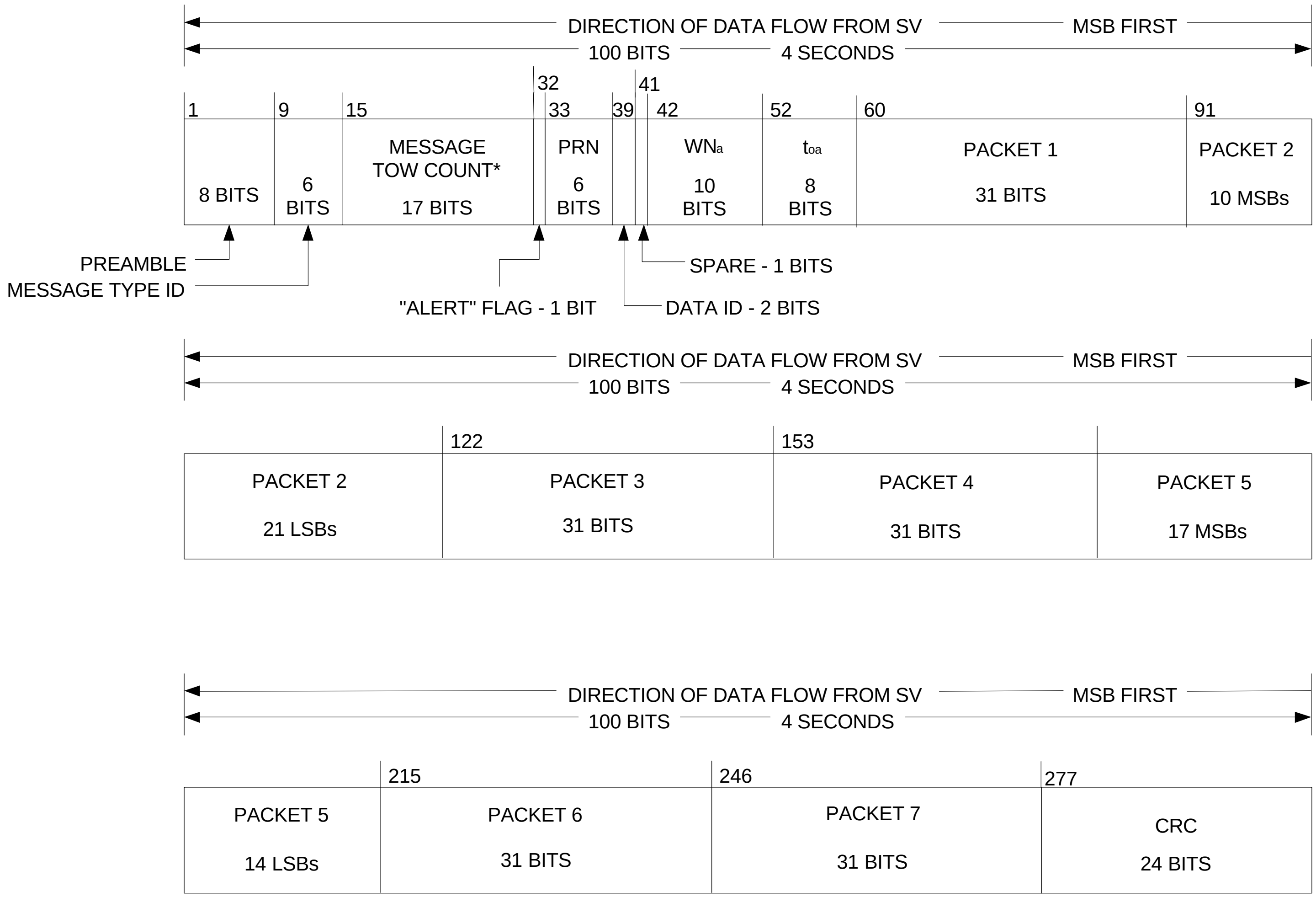


Figure 30-5. Message Type 5 Format



* MESSAGE TOW COUNT = 17 MSBs OF ACTUAL TOW COUNT AT START OF NEXT 12-SECOND MESSAGE

Figure 30-6. Message Type 6 Format

30.3.3.1 Message Type 1 Clock, Health and Accuracy Parameters.

30.3.3.1.1 Message Type 1 Clock, Health and Accuracy Parameter Content. The clock parameters in Message Type 1 describe the SV time scale during the period of validity. The parameters in a data set shall be valid during the interval of time in which they are transmitted and shall remain valid for an additional period of time after transmission of the next data set has started.

30.3.3.1.1.1 Transmission Week Number. The ten bits starting at bit 39 shall contain the ten MSBs of the 29-bit Z-count as qualified in paragraph 20.3.3.3.1.1.

30.3.3.1.1.2 SV Accuracy (L2). Bits 55 through 58 shall contain the URA index of the SV (reference paragraph 6.2.1) for the unauthorized (non-Precise Positioning Service) user. The URA index (N) is an integer in the range of 0 through 15 and follows the same rules as defined in paragraph 20.3.3.3.1.3.

30.3.3.1.1.3 Signal Health. The five-bit health indication in bits 49 through 53 refers to the transmitting SV for the broadcast signal. The health indication is TBD

30.3.3.1.1.4 Issue of Data, Clock (IODC). Bits 201 through 210 shall contain the IODC. The IODC indicates the issue number of the data set and thereby provides the user with a convenient means of detecting any change in the correction parameters. Constraints on the IODC as well as the relationship between the IODC and the IODE (issue of data, ephemeris) terms are defined in paragraph 30.3.4.4.

30.3.3.1. 1.5 Short-term and Long -term Extended Operations. Whenever the fit interval flag indicates a fit interval greater than 4 hours, the IODC can be used to determine the actual fit interval of the data set (reference section 30.3.4.4).

30.3.3.1.1.6 SV Clock Correction. Message Type 1 contains the parameters needed by the users for apparent SV L1/L2 clock correction (t_{oc}, a_{f2}, a_{f1}, a_{f0}). The related algorithm is given in paragraph 20.3.3.3.3.1.

30.3.3.1.2 Message Type 1 Clock, Health and Accuracy Parameter Characteristics. For those parameters whose characteristics are not fully defined in Section 30.3.3.1.1, the number of bits, the scale factor of the LSB (which is the last bit received), the range, and the units shall be as specified in Table 30-I.

30.3.3.1.3 User Algorithms for Message Type 1 Clock Data. The algorithms defined in paragraph 20.3.3.3.3.1 allow all users to correct the code phase time received from the SV with respect to both SV code phase offset and relativistic effects. However, since the SV clock corrections of equations in paragraph 20.3.3.3.3.1 are estimated by the CS using dual frequency L1 and L2 P(Y) code measurements, the single-frequency L1 or L2 user and the dual frequency L1 C/A - L2C user must apply additional terms to the SV clock corrections equations. These terms are described in paragraph 30.3.3.3.1.5.

Table 30-I. Message Type 1 Clock, Health and Accuracy Parameters

Parameter	No. of Bits**	Scale Factor (LSB)	Effective Range***	Units
Week No.	10	1		weeks
SV accuracy (URA)	4			(see text)
SV health (L1/L2)	6	1		discrete
IODC	10			(see text)
t_{oc}	16	2^{4}	604,784	seconds
a_{f2}	8*	2^{-55}		sec/sec^{2}
a_{f1}	16*	2^{-43}		sec/sec
a_{f0}	22*	2^{-31}		seconds

* Parameters so indicated are two's complement, with the sign bit (+ or -) occupying the MSB;

** See Figure 30-1 for complete bit allocation in Message Type 1;

*** Unless otherwise indicated in this column, effective range is the maximum range attainable with indicated bit allocation and scale factor.

30.3.3.2 Message Type 1 and 2 Ephemeris Parameters

30.3.3.2.1 Message Type 1 and 2 Ephemeris Parameter Content. The contents of the ephemeris representation parameters in Message Types 1 and 2 are defined below, followed by material pertinent to the use of the data.

The ephemeris parameters describe the orbit of the transmitting SV during the curve fit intervals described in section 30.3.4. Table 20-II gives the definition of the orbital parameters using terminology typical of Keplerian orbital parameters; it is noted, however, that the transmitted parameter values are expressed such that they provide the best trajectory fit in Earth-Centered, Earth-Fixed (ECEF) coordinates for each specific fit interval. The user shall not interpret intermediate coordinate values as pertaining to any conventional coordinate system.

The issue of ephemeris data (IODE) term provides the user with a convenient means for detecting any change in the ephemeris representation parameters. The IODE is provided in Message Type 2 for the purpose of comparison with the 10 bits of the IODC term in Message Type 1. Whenever these two terms do not match, a data set cutover has occurred and new data must be collected. The timing of the IODE and constraints on the IODC and IODE are defined in paragraph 30.3.4.4.

Any change in the Message Type 1 and 2 data will be accomplished with a simultaneous change in both the IODC and IODE words. The CS will assure that the t_{oe} *value, for at least the first data set transmitted by an SV after an upload, is different from that transmitted prior to the cutover.*

A "fit interval" flag is provided in Message Type 2 to indicate whether the ephemerides are based on a four-hour fit interval or a fit interval greater than four hours (reference paragraph 30.3.3.2.3.1).

30.3.3.2.2 Message Type 1 and 2 Ephemeris Parameter Characteristics. For each ephemeris parameter contained in Message Types 1 and 2, the number of bits, the scale factor of the LSB (which is the last bit received), the range, and the units are as specified in Table 20-III. See Figures 30-1 and 30-2 for complete bit allocation in Message Types 1 and 2.

30.3.3.2.3 User Algorithm for Ephemeris Determination. The user shall compute the ECEF coordinates of position for the phase center of the SVs' antennas utilizing a variation of the equations shown in Table 20-IV. The ephemeris parameters are Keplerian in appearance; the values of these parameters, however, are produced by the CS via a least squares curve fit of the predicted ephemeris of the phase center of the SVs' antennas (time-position quadruples; t, x, y, z expressed in ECEF coordinates). Particulars concerning the periods of the curve fit, the resultant accuracy, and the applicable coordinate system are given in the following subparagraphs.

30.3.3.2.3.1 Curve Fit Intervals. Bit 275 of Message Type 2 is a "fit interval" flag which indicates the curve-fit interval used by the CS in determining the ephemeris parameters, as follows:

0 = 4 hours,

1 = greater than 4 hours.

The relationship of the curve-fit interval to transmission time and the timing of the curve-fit intervals is covered in section 30.3.4.

30.3.3.2.3.2 Parameter Sensitivity. See paragraph 20.3.3.4.3.2.

30.3.3.2.3.3 Coordinate Systems

30.3.3.2.3.3.1 ECEF Coordinate System. See paragraph 20.3.3.4.3.3.1.

30.3.3.2.3.3.2 Earth-Centered Inertial (ECI) Coordinate System. See paragraph 20.3.3.4.3.3.2.

30.3.3.2.3.4 Geometric Range. See paragraph 20.3.3.4.3.4.

30.3.3.3 Message Type 3 Parameters. The contents of Message Type 3 are defined below, followed by material pertinent to the use of the data.

30.3.3.3.1 Message Type 3 Parameter Content. Message Type 3 contains UTC and ionospheric parameters and other data.

30.3.3.3.1.1 Coordinated Universal Time (UTC) and GPS Time Parameters. Message Type 3 shall contain the parameters related to correlating UTC(USNO) time with GPS Time. The bit length, scale factors, ranges, and units of these parameters are given in Table 20-IX. The related algorithms are described in paragraph 30.3.3.3.2.1.

The UTC(USNO) and GPS Time parameters shall be updated by the CS at least once every six days while the CS is able to upload the SVs. If the CS is unable to upload the SVs, the accuracy of the UTC parameters transmitted by the SVs will degrade over time.

30.3.3.3.1.2 Ionospheric Data. The ionospheric parameters which allow the "L1 only", or "L2 only" user to utilize the ionospheric model (reference paragraph 30.3.3.3.2.2) for computation of the ionospheric delay are contained in Message Type 3. The bit lengths, scale factors, ranges, and units of these parameters are given in Table 20-X. See Figure 30-3 for complete bit allocation in Message Type 3.

The ionospheric data shall be updated by the CS at least once every six days while the CS is able to upload the SVs. If the CS is unable to upload the SVs, the ionospheric data transmitted by the SVs may not be accurate.

30.3.3.3.1.3 SV Health (L1/L2/L5). The three-bit health indication in bits 245 through 247 refers to the transmitting SV for the L1, L2 and L5 signals. The health indication is TBD

Additional SV health data are given in Message Types 4 and 6, the Almanac message. The data given in Message Type 1 may differ from that shown in Message Types 4 and 6 on other SVs since the latter may be updated at a different time.

30.3.3.3.1.4 Data ID. Bits 39 and 40 of Message Type 3 (and the same bits in Message Types 4 and 5) shall contain the data ID which defines the applicable GPS NAV data structure. Data ID one (denoted by binary code 00) was utilized during Phase I of the GPS program and is no longer in use; data ID two (denoted by binary code 01) is used on the L1 and L2 C/A and P(Y) code signals. Data ID three (denoted by binary 10) is used on the L5 signal. Data ID four (denoted by binary 11) is used on the L2 2CM signal.

30.3.3.3.1.5 Estimated L1 – L2 Group Delay Differential. The group delay correction terms, T_{GD12}, T_{GD1PC}, T_{GD2PC}, *for the benefit of single frequency L1-P, L1-C/A, L2-P, L2C users and dual frequency L1/L2 users is contained in bits 209 through 232 of Message Type 3. The bit length, scale factors, ranges, and units of these parameters are given in Table 30-II. See Figure 30-3 for complete bit allocation in Message Type 3. The related user algorithms are given in paragraphs 30.3.3. 3.2.3 and 30.3.3.3.2.4.*

30.3.3.3.2 Algorithms Related to Message Type 3 Data. The following algorithms shall apply when interpreting Coordinated Universal Time, Ionospheric Model data, and Group Delay Differential data in the NAV message.

30.3.3.3.2.1 Coordinated Universal Time (UTC) and GPS Time. Message Type 3 includes: (1) the parameters needed to relate GPS Time to UTC(USNO), and (2) notice to the user regarding the scheduled future or recent past (relative to NAV message upload) value of the delta time due to leap seconds (Dt_{LSF})*, together with the week number* (WN_{LSF}) *and the day number (DN) at the end of which the leap second becomes effective. Information required to use these parameters to calculate* t_{UTC} *is in paragraph 20.3.3.5.2.4.*

30.3.3.3.2.2 Ionospheric Model. The "two frequency" (L1 C/A and L2 2C) user shall correct the time received from the SV for ionospheric effect by utilizing the time delay differential between L1 and L2 (reference paragraph 30.3.3. 3.2.4). The "one frequency" user, however, should use the model given in paragraph 20.3.3.5.2.5 to make this correction.

Table 30-II. Group Delay Differential Parameters

Parameter	No. of Bits**	Scale Factor (LSB)	Effective Range***	Units
T_{GD12}	8*	2^{-31}		seconds
T_{GD1PC}	8*	2^{-31}		seconds
T_{GD2PC}	8*	2^{-31}		seconds

* Parameters so indicated are two's complement with the sign bit (+ or -) occupying the MSB;

** See Figure 30-3 for complete bit allocation in Message Type 3;

*** Unless otherwise indicated in this column, effective range is the maximum range attainable with indicated bit allocation and scale factor;

30.3.3.3.2.3 L1/L2 Group Delay Correction. The L1 and L2 correction term, T_{GD12}, is monitored to account for the effect of SV group delay differential between L1 P code and L2 P code. The single frequency L1 or L2 P code user should use the equations in paragraph 20.3.3.3.3.2. For maximum accuracy, the single frequency L1 C/A user must make further modifications to the code phase offset given by:

$$(Dt_{SV})_{L1,C/A} = Dt_{SV} - T_{GD12} + T_{GD1PC}$$

where T_{GD12} and T_{GD1PC} are provided to the user as Message Type 3 data, described in paragraph 30.3.3.3.1.5. For maximum accuracy, the single frequency L2C user code phase modification is given by

$$(Dt_{SV})_{L2,2C} = Dt_{SV} - g_{12}T_{GD12} + T_{GD2PC}$$

where, denoting the nominal center frequencies of L1 and L2 as f_{L1} and f_{L2} respectively,

$$g_{12} = (f_{L1}/f_{L2})^2 = (1575.42/1227.6)^2 = (77/60)^2$$

and where, T_{GD2PC} is provided to the user as Message Type 3 data.

The values of T_{GD1PC} and T_{GD2PC} are equal to the mean SV group delay differential between the P(Y) code and the C/A or L2C codes respectively as follows,

$$T_{GD1PC} = t_{L1,P} - t_{L1,C/A}$$

$$T_{GD2PC} = t_{L2,P} - t_{L2,C/A}.$$

30.3.3.3.2.4 L1 /L2 Ionospheric Correction. The two frequency (L1 C/A-code and L2C -code) user shall correct for the group delay due to ionospheric effects by applying the relationship:

$$PR = \frac{(PR_{L2C} + cT_{GD2PC}) - \gamma_{12}(PR_{L1,C/A} + cT_{GD1PC})}{1 - \gamma_{12}}$$

where,

PR = pseudorange corrected for ionospheric effects,

PR_i = pseudorange measured on the channel indicated by the subscript,

and

c = speed of light.

30.3.3.4 Message Type 4 Almanac Parameters. The contents of Message Type 4 are defined below, followed by material pertinent to the use of the data.

30.3.3.4.1 Message Type 4 Almanac Parameter Content. Message Type 4 contains almanac data.

30.3.3.4.1.1 Almanac Data. Message Type 4 contains the almanac data and SV health words for up to 37 SVs (the health words are discussed in paragraphs 30.3.3.1.1.3 and 30.3.3.3.1.3). The almanac data are a reduced-precision subset of the clock and ephemeris parameters. The number of bits, the scale factor (LSB), the range, and the units of the almanac parameters are given in Table 20-VI. The algorithms and other material related to the use of the almanac data are given in paragraph 30.3.3.4.2.

The almanac parameters shall be updated by the CS at least once every 6 days while the CS is able to upload the SVs. If the CS is unable to upload the SVs, the accuracy of the almanac parameters transmitted by the SVs will degrade over time.

30.3.3.4.1.2 SV Health (L1 and L2). Message Type 4 contains the eight-bit L1/L2 health words defined in paragraph 20.3.3.5.1.3 and Table 20-VII.

The data given in Message Type 1 of the other SVs may differ from that shown in Message Type 4 since the latter may be updated at a different time.

The predicted health data will be updated at the time of upload when a new almanac has been built by the CS. The transmitted health data may not correspond to the actual health of the transmitting SV or other SVs in the constellation.

30.3.3.4.1.3 Anti-Spoof (A-S) Flags and SV Configurations. Bits 225 to 228 of Message Type 4 shall contain a four-bit-long term for each of up to 37 SVs to indicate the A-S status (of the L1 and L2 signals) and the configuration code of each SV. The terms are defined in paragraph 20.3.3.5.1.6.

30.3.3.4.1.4 Almanac Reference Week. Bits 47 through 56 of Message Type 4 shall indicate the number of the week (WN_a) to which the almanac reference time (t_{oa}) is referenced (see paragraphs 30.3.3.4.1.1 and 30.3.3.4.2.2). The WN_a term consists of ten bits which shall be a Modulo 1024 binary representation of the GPS week number (see paragraph 6.2.4) to which the t_{oa} is referenced. Bits 73 through 80 of Message Type 4 shall contain the value of t_{oa}, which is referenced to this WN_a.

30.3.3.4.2 Algorithms Related to Message Type 4 Data. The following algorithms shall apply when interpreting Almanac data in the NAV message.

30.3.3.4.2.1 Almanac. The almanac is a subset of the clock and ephemeris data, with reduced precision. The user algorithm is essentially the same as the user algorithm used for computing the precise ephemeris from the Message Type 1 and 2 parameters (see paragraph 30.3.3.2.3). The almanac content for one SV is given in Table 20-VI. Important information about the almanac calculation is contained in paragraph 20.3.3.5.2.1.

30.3.3.4.2.2 Almanac Reference Time. See the two subparagraphs labeled Normal and Short-term Extended Operations and Long-term Extended Operations of paragraph 20.3.3.5.2.2.

30.3.3.4.2.3 Almanac Time Parameters. See paragraph 20.3.3.5.2.3.

30.3.3.5 Message Type 5. Message Type 5 is reserved for special messages with the specific contents at the discretion of the Operating Command. It can accommodate the transmission of 29 eight-bit ASCII characters. The requisite 232 bits occupy bits 41 through 272 of Message Type 5. The eight-bit ASCII characters shall be limited to the set described in paragraph 20.3.3.5.1.10.

30.3.3.6 Message Type 6 Reduced Almanac Parameters. The contents of Message Type 6 are defined below, followed by material pertinent to the use of the data.

30.3.3.6.1 Message Type 6 Reduced Almanac Parameter Content. Message Type 6 contains reduced set of almanac data for up to 7 SVs in each 12-second message.

30.3.3.6.1.1 Reduced Almanac Data. Message Type 6 contains the reduced almanac data and SV health words for up to 37 SVs (the health words are discussed in paragraphs 30.3.3.1.1.3 and 30.3.3.3.1.3). The reduced almanac data of a SV is broadcast in a packet of 31 bits long as described in Figure 30-7. Each Message Type 6 contains 7 packets providing reduced almanac data for up to 7 SVs. The reduced almanac data are a subset of the almanac data which provide less precise ephemeris of which values are provided relative to pre-specified reference values. The number of bits, the scale factor (LSB), the range, and the units of the reduced almanac parameters are given in Table 30-III. The algorithms and other material related to the use of the reduced almanac data are given in paragraph 30.3.3.6.2.

The reduced almanac parameters shall be updated by the CS at least once every 6 days while the CS is able to upload the SVs. If the CS is unable to upload the SVs, the accuracy of the reduced almanac parameters transmitted by the SVs will degrade over time.

30.3.3.6.1.2 Almanac Reference Week. Bits 42 through 51 of Message Type 6 shall indicate the number of the week (WN_a) to which the almanac reference time (t_{oa}) is referenced (see paragraph 30.3.3.6.1.3). The WN_a term consists of ten bits which shall be a Modulo 1024 binary representation of the GPS week number (see paragraph 6.2.4) to which the t_{oa} is referenced. Bits 52 through 59 of Message Type 6 shall contain the value of t_{oa}, which is referenced to this WN_a.

30.3.3.6.1.3 Almanac Reference Time. See the two subparagraphs labeled Normal and Short-term Extended Operations and Long-term Extended Operations of paragraph 20.3.3.5.2.2.

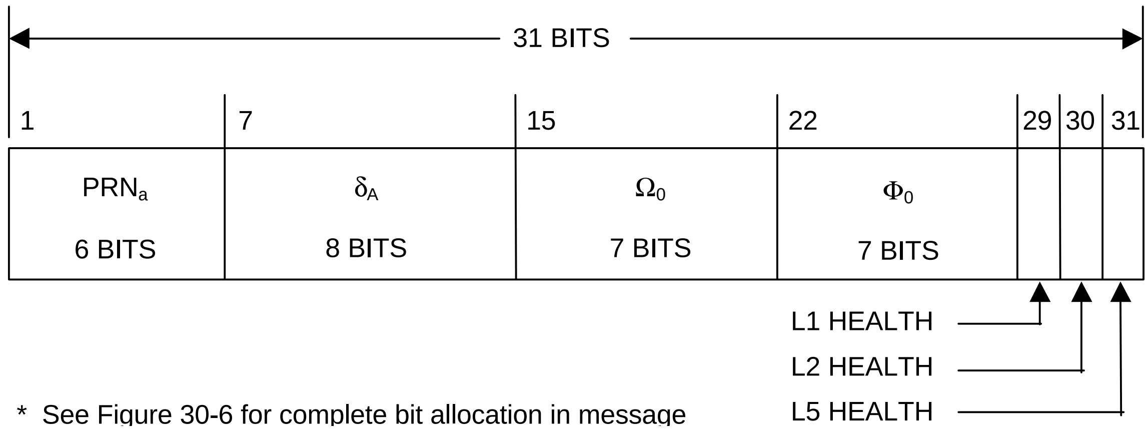


Figure 30-7. Reduced Almanac Packet

Table 30-III. Reduced Almanac Parameters *****				
Parameter	*No. of Bits*	*Scale Factor (LSB)*	*Effective Range ** *	*Units*
d_A ***	8 *	2^{+9}		meters
W_0	7 *	2^{-6}		semi-circles
F_0 ****	7 *	2^{-6}		semi-circles

* *Parameters so indicated shall be two's complement with the sign bit (+ or -) occupying the MSB;*

** *Unless otherwise indicated in this column, effective range is the maximum range attainable with indicated bit allocation and scale factor;*

*** *Relative to* A_{ref} = *26,559,710 meters;*

**** F_0 = *Argument of Latitude at Reference Time* = $M_0 + w$;

***** *Relative to following reference values:*

$e = 0$

d_i = +0.0056 seimi-circles (i = 55 degrees)

$\dot{W} = -2.5 \times 10^{-9}$ semi-circles/second.

30.3.3.6.2 Reduced Almanac Packet. The following shall apply when interpreting the data provided in each packet of reduced almanac.

30.3.3.6.2.1 SV PRN Number. Bits 1 through 6 in each packet of Message Type 6 shall specify PRN number of the SV whose reduced almanac is provided in the same packet.

30.3.3.6.2.2 Reduced Almanac. The reduced almanac data is provided in bits 7 through 28 of each packet. The data from a packet along with the reference values (see Table 30-III) provide ephemeris with further reduced precision. The user algorithm is essentially the same as the user algorithm used for computing the precise ephemeris from the Message Type 1 and 2 parameters (see paragraph 30.3.3.2.3 and Table 20-IV). Other parameters appearing in the equations of Table 20-IV, but not provided by the reduced almanac with the reference values, are set to zero for SV position determination.

30.3.3.6.2.3 SV Health (L1/L2/L5). The three-bit health indication in bits 29 through 31 of each packet refers to the L1, L2, and L5 signals of the SV whose PRN number is specified in bits 1 through 6 of the same packet. The health indication is TBD.

The data given in Message Types 1, 3, and 4 of the other SVs may differ from that shown in Message Type 6 since the latter may be updated at a different time.

The predicted health data will be updated at the time of upload when a new almanac has been built by the CS. The transmitted health data may not correspond to the actual health of the transmitting SV or other SVs in the constellation.

30.3.4 Timing Relationships. The following conventions shall apply.

30.3.4.1 Paging and Cutovers. Paging of messages is completely arbitrary, but sequenced to provide optimum user performance. Message types 1 and 2 shall be broadcast consecutively.

30.3.4.2 SV Time vs. GPS Time. In controlling the SVs and uploading of data, the CS shall allow for the following timing relationships:

- *a. Each SV operates on its own SV time;*
- *b. All time-related data (TOW) in the messages shall be in SV-time;*
- *c. All other data in the NAV message shall be relative to GPS time;*
- *d. The acts of transmitting the NAV messages shall be executed by the SV on SV time.*

30.3.4.3 Speed of Light. See paragraph 20.3.4.3.

30.3.4.4 Data Sets. The IODE is a 10 bit number equal to the 10 bit IODC of the same data set. The transmission of IODC and IODE values in different data sets shall be such that the transmitted IODC and IODE will be different from any value transmitted by the SV during the preceding seven days. The range of IODC will be as given in Table 20-XII.

Cutovers to new data sets follow the rules in the second subparagraph of paragraph 20.3.4.4.

The start of the transmission interval for each data set corresponds to the beginning of the curve fit interval for the data set. Each data set remains valid for the duration of its curve fit interval.

Normal Operations. Message Type 1 and 2 data sets are transmitted by the SV for periods of one hour. The corresponding curve fit interval is four hours.

Short-term and Long-term Extended Operations. The transmission intervals and curve fit intervals with the applicable IODC/IODE ranges are given in Table 20-XII.

30.3.4.5 Reference Times. See paragraph 20.3.4.5.

30.3.5 Data Frame Parity. The data signal contains parity coding according to the following conventions.

30.3.5.1 Parity Algorithm. Twenty-four bits of CRC parity will provide protection against burst as well as random errors with a probability of undetected error £ 2^{-24} = 5.96´10^{-8} for all channel bit error probabilities £ 0.5. The CRC word is calculated in the forward direction on a given message using a seed of 0. The sequence of 24 bits (p_1,p_2,...,p_{24}) is generated from the sequence of information bits (m_1,m_2,...,m_{276}) in a given message. This is done by means of a code that is generated by the polynomial

$$g(X) = \sum_{i=0}^{24} g_i X^i$$

where

$$\begin{aligned} g_i &= 1 \text{ for } i = 0, 1, 3, 4, 5, 6, 7, 10, 11, 14, 17, 18, 23, 24 \\ &= 0 \text{ otherwise} \end{aligned}$$

This code is called CRC-24Q (Q for Qualcomm Corporation). The generator polynomial of this code is in the following form (using binary polynomial algebra):

$$g(X) = (1 + X)p(X)$$

where p(X) is the primitive and irreducible polynomial

$$\begin{aligned} p(X) = {} & X^{23} + X^{17} + X^{13} + X^{12} \\ & + X^{11} + X^{9} + X^{8} + X^{7} + X^{5} + X^{3} + 1 \end{aligned}$$

When, by the application of binary polynomial algebra, the above g(X) is divided into $m(X)X^{24}$*, where the information sequence m(X) is expressed as*

$$m(X) = m_k + m_{k-1}X + m_{k-2}X^2 + \cdots + m_1 X^{k-1}$$

The result is a quotient and a remainder R(X) of degree < 24. The bit sequence formed by this remainder represents the parity check sequence. Parity bit p_i*, for any i from 1 to 24, is the coefficient of* X^{24-i} *in R(X).*

This code has the following characteristics:

1) It detects all single bit errors per code word.

2) It detects all double bit error combinations in a codeword because the generator polynomial g(X) has a factor of at least three terms.

3) It detects any odd number of errors because g(X) contains a factor 1+X.

4) It detects any burst error for which the length of the burst is £ 24 bits.

5) It detects most large error bursts with length greater than the parity length r = 24 bits. The fraction of error bursts of length b > 24 that are undetected is:

a) $2^{-24} = 5.96$ ´ 10^{-8}*, if b > 25 bits.*

b) $2^{-23} = 1.19$ ´ 10^{-7}*, if b = 25 bits.*