RECOMMENDATION ITU-R M.823-1*

TECHNICAL CHARACTERISTICS OF DIFFERENTIAL TRANSMISSIONS FOR GLOBAL NAVIGATION SATELLITE SYSTEMS (GNSS) FROM MARITIME RADIO BEACONS IN THE FREQUENCY BAND 283.5-315 kHz IN REGION 1 AND 285-325 kHz IN REGIONS 2 AND 3

(Question ITU-R 58/8)

(1992-1995)

Summary

Many Administrations are implementing transmissions from radio beacon stations of differential corrections for GNSS. This Recommendation contains the technical characteristics to which such transmissions should conform for corrections to the GPS and GLONASS Navigation Satellite Systems.

The Recommendation also describes the various types of differential correction messages used for those navigation satellite systems and the message format. In addition, it contains details of message transmission schedules.

The ITU Radiocommunication Assembly,

considering

a) Resolution No. 602 of the World Administrative Radio Conference for the Mobile Services (Geneva, 1987);

b) that according to No. 466 of the Radio Regulations, in the band 285-325 kHz (283.5-325 kHz in Region 1) in the maritime radionavigation service, radio beacon stations may also transmit supplementary navigational information using narrow-band techniques, on condition that the prime function of the beacon is not significantly degraded;

c) Recommendation ITU-R M.631 on the use of hyperbolic maritime radionavigation systems in the band 283.5-315 kHz;

d) the technical characteristics set out in the Final Acts of the Regional Administrative Conference for the Planning of the Maritime Radionavigation Service (radio beacons) in the European Maritime Area (Geneva, 1985);

e) that the navigational accuracy expected to be available from GNSS will be 60-100 m (with 95% probability) for general use;

f) that this accuracy, whilst adequate for most general navigation requirements, will not be enough for some specialized navigation, such as in confined waterways and harbour approaches or for the position sensor in electronic chart systems;

g) that other specialized maritime applications, such as fishing, navigational surveying, dredging, cable and pipe laying, positioning of buoys and other offshore structures may require higher accuracy than that available from GNSS for general use;

h) that the navigational accuracy and integrity of GNSS can be improved considerably by the transmission of differential corrections from suitably located reference stations;

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* This Recommendation should be brought to the attention of the International Maritime Organization (IMO), the International Civil Aviation Organization (ICAO), the International Association of Lighthouse Authorities (IALA) and the International Maritime Radio Association (CIRM).

j) that technical, economic and administrative factors indicate that the use of maritime radio beacons would be one feasible solution for the transmission of differential corrections;

k) that propagation of transmissions from maritime radio beacons is predominantly by ground wave with a usable range that does not exceed the range of applicability of the reference station corrections;

l) that maritime radio beacons currently provide coverage of coastal waters in many parts of the world, enabling a worldwide standard for these differential transmissions to be introduced efficiently and economically;

m) that, although present studies have specifically addressed transmission of corrections for GPS/GLONASS, the same principles apply to terrestrial radionavigation systems, such as Loran-C/Chayka,

recommends

1 that the technical characteristics of a differential correction service for GNSS using maritime radio beacons, in the frequency band 285-325 kHz (283.5-315 kHz in Region 1), and for associated receivers, should be in accordance with the characteristics given in Annex 1.

ANNEX 1

System characteristics for differential GNSS

1 Technical characteristics

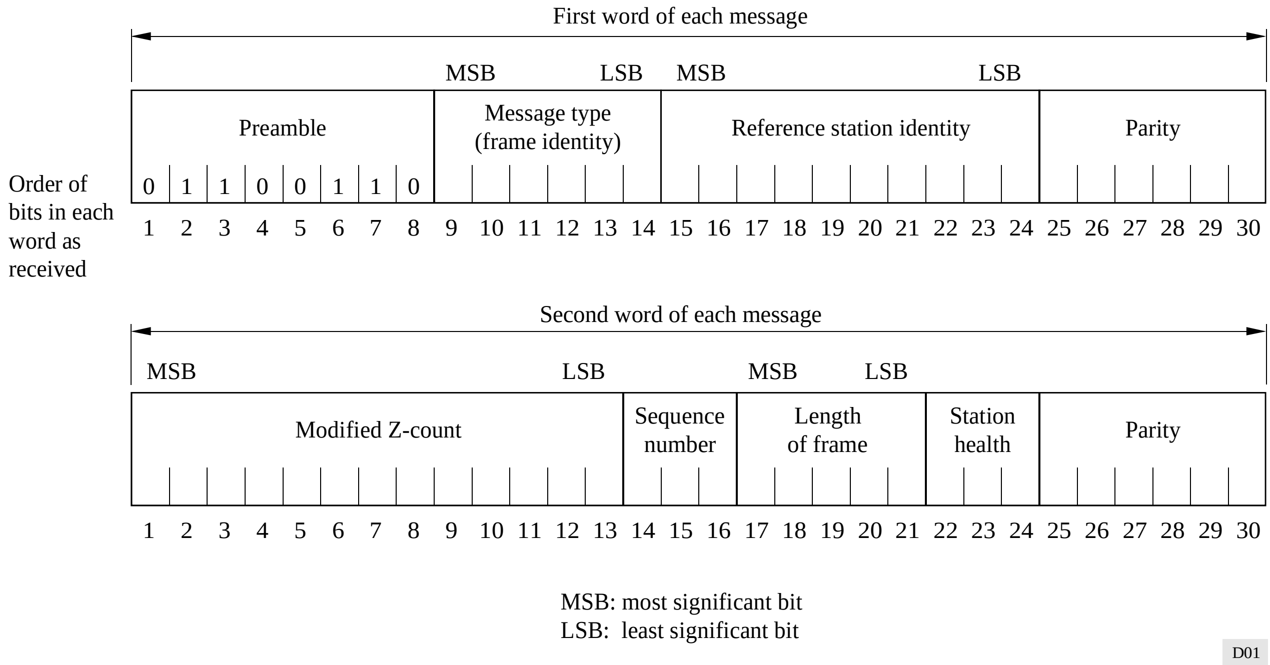
1.1 The carrier frequency of the differential correction signal of a radio-beacon station is an integer multiple of 500 Hz.

1.2 Frequency tolerance of the carrier is ± 2 Hz.

1.3 The general message format is as shown in Fig. 1 which details the first two 30 bit words of each frame or message type. Each frame is $N + 2$ words long, N words containing the data of the message. The minimum message types available for transmission are as shown in Table 1. Details of these message type contents and formats are as shown in Figs. 2-6 for GPS and Figs. 7-11 for GLONASS. The parity algorithm used links 30 bit words within and across sub-frames of 10 words, using the (32,26) Hamming Code. Type 6 or 34 ($N = 0$ or $N = 1$) messages should be used if no other message type is available.

FIGURE 1

Two-word header for all messages



Station health bits:

111 Shall cause the user equipment to indicate that the reference station is not working properly.

110 Shall cause the user equipment to indicate that the transmission is unmonitored.

Other codes are defined by the service provider for healthy broadcasts.

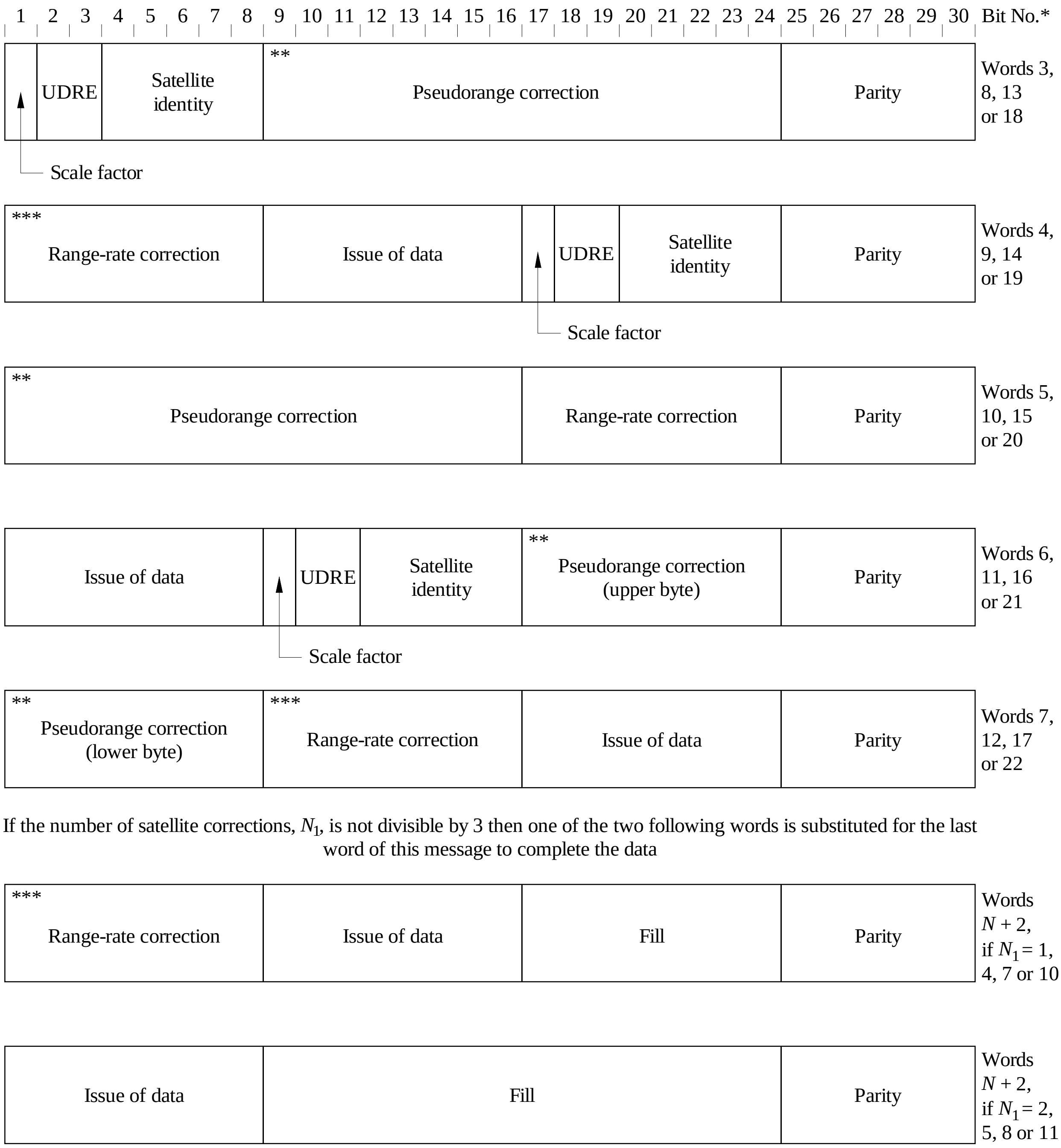
TABLE 1

Message types

GPS message type number	Title	GLONASS message type number
1	Differential GNSS corrections (full set of satellites)	31
3	Reference station parameters	32
5	Constellation health	33
6	Null frame	34 ($N = 0$ or $N = 1$)
7	Radio beacon almanacs	35
9	Subset differential GNSS corrections (this may replace Types 1 or 31)	34 ($N > 1$)
16	Special message	36

FIGURE 2

Type 1 and Type 9 message formats
Differential GPS corrections



UDRE: user differential range error.

* As received.

** Binary 1000 0000 0000 0000 indicates a problem and user equipment should immediately stop using this satellite.

*** Binary 1000 0000 indicates a problem and user equipment should immediately stop using this satellite.

Note 1 - In Type 1 messages the data from all satellites in view are transmitted. In Type 9 messages only the data from a subset of satellites are transmitted.

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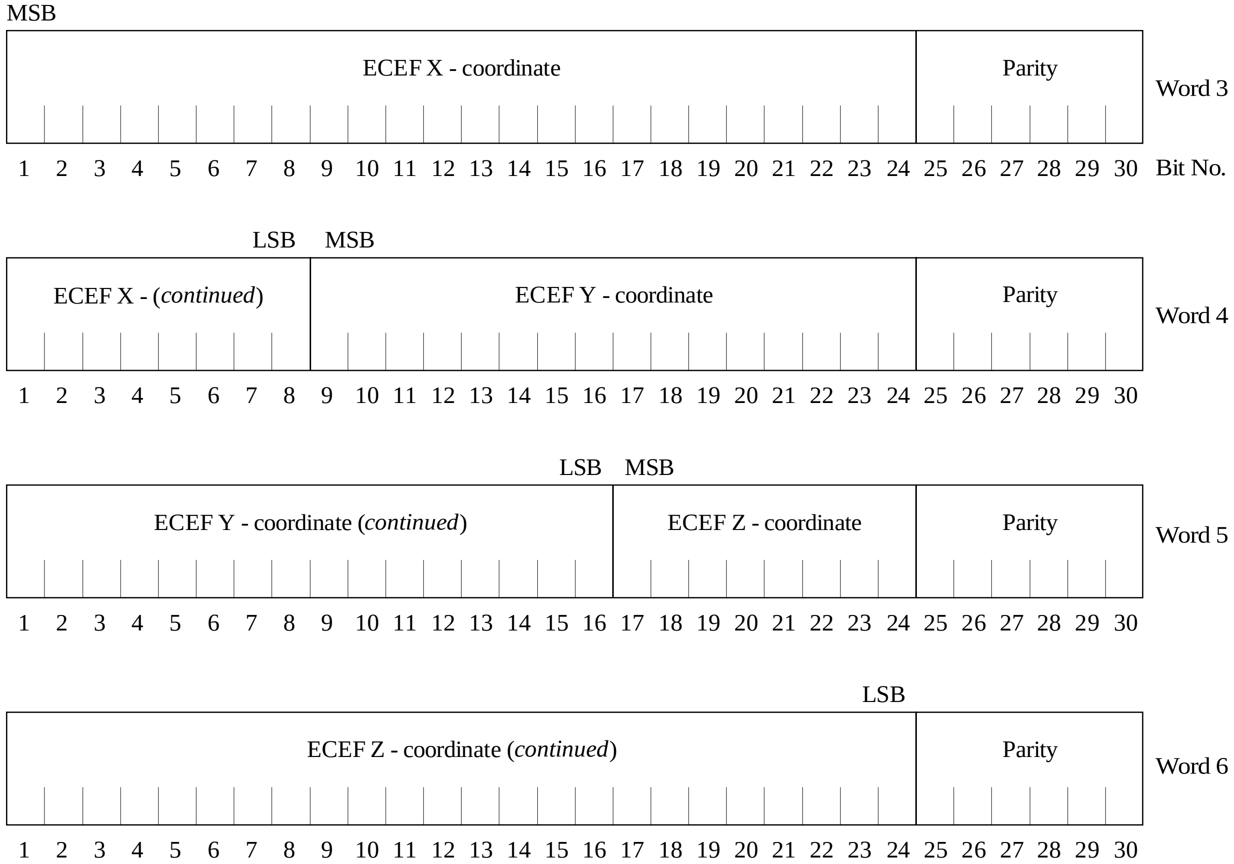
FIGURE 3

Type 3 message format
Reference station parameters (GPS)



MSB: most significant bit
LSB: least significant bit
ECEF: Earth-centred, Earth-fixed, WGS-84, unless otherwise specified by service provider

D03

FIGURE 4

Type 5 message format
Constellation health (GPS)

(see Table 2)

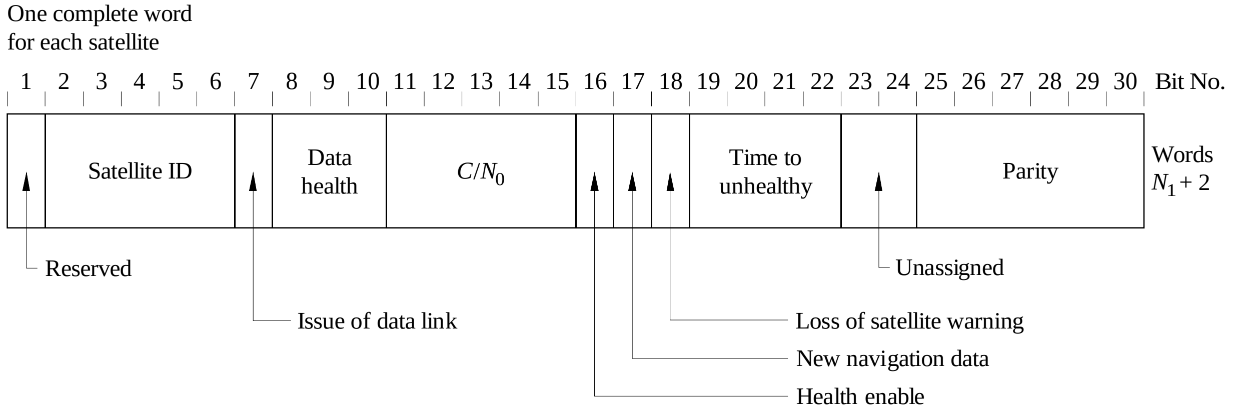


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TABLE 2

Contents of Type 5 and 33 messages

Parameter	Bit No.	Explanation
Reserved	1	A simple bit reserved for possible future expansion of satellite numbers beyond 32
Satellite ID	2-6	Standard format (1-32, 32 is indicated with all zeros)
IOD link (GPS) T_b link (GLONASS)	7	Bit set to "0" indicates this information refers to navigation data with IOD or T_b in message Types 1 and 9 (GPS) or 31, 34 (GLONASS)
Data health (B_n – GLONASS)	8-10	Standard information concerning satellite navigation data health. For GPS three zeros indicate all data is valid, any of the three bits set to "1" indicates a problem with some or all of the data. For GLONASS, bit 8 set to "1" indicates satellite is unhealthy, bit 8 set to "0" indicates satellite is healthy; the second and the third bits are spares and are disregarded by the user equipment
C/N_0	11-15	Satellite signal-to-noise ratio as measured at reference station. Scale factor 1 dB(Hz). Range is 25 to 55 dB(Hz). Bit 15 is LSB. The value "00000" indicates that the satellite is not being tracked by the reference station. The value "00001" = 25 dB(Hz) at the low end and the value "11111" = 55 dB(Hz) at the high end
Health enable	16	Bit set to 1 indicates that satellite can be considered healthy by DGPS/DGLONASS user equipment despite the fact that satellite navigation data indicates the satellite is unhealthy
New navigation data	17	Bit set to 1 indicates that new satellite navigation data is being acquired by the reference station and being integrated into the pseudorange correction generation process. There will soon be a new IOD/T_b indicated in the Type 1/31 or 9/34 messages
Loss of satellite warning	18	Bit set to 1 indicates that a change in the satellite's health to "unhealthy" is scheduled. The "healthy" time remaining is estimated by the following 4 bits
Time to unhealthy	19-22	See bit 18 above. Scale factor is 5 min. Range is 0 to 75 min. Bit 22 is LSB. The value "0000" indicates that the satellite is about to go "unhealthy". The value "1111" indicates the satellite will go "unhealthy" in about 75 min
Unassigned	23-24	
Parity	25-30	

Type 6 message format
Null frame (GPS)

The Type 6 message contains no parameters. It will be used as transmission fill, if required. Its purpose is to provide messages when the reference station has no other message ready to send, or to synchronize the beginning of a message to some unspecified epoch.

The message contains the first two words as usual with $N = 0$ or 1, depending whether an even or odd transmission fill is required. If $N = 1$, then the 24 data bits in the extra word should be filled with alternating 1's and 0's. Parity should be tested as usual.

FIGURE 5

Type 7 message format
Beacon almanac (GPS)

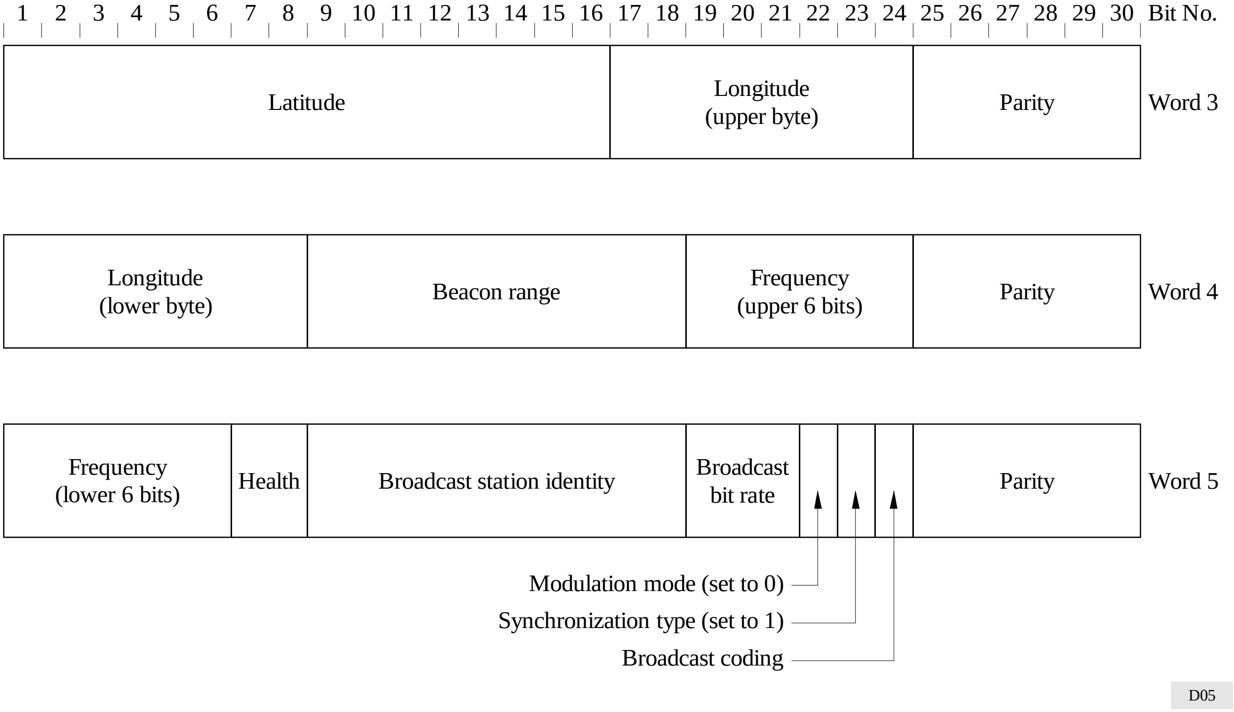
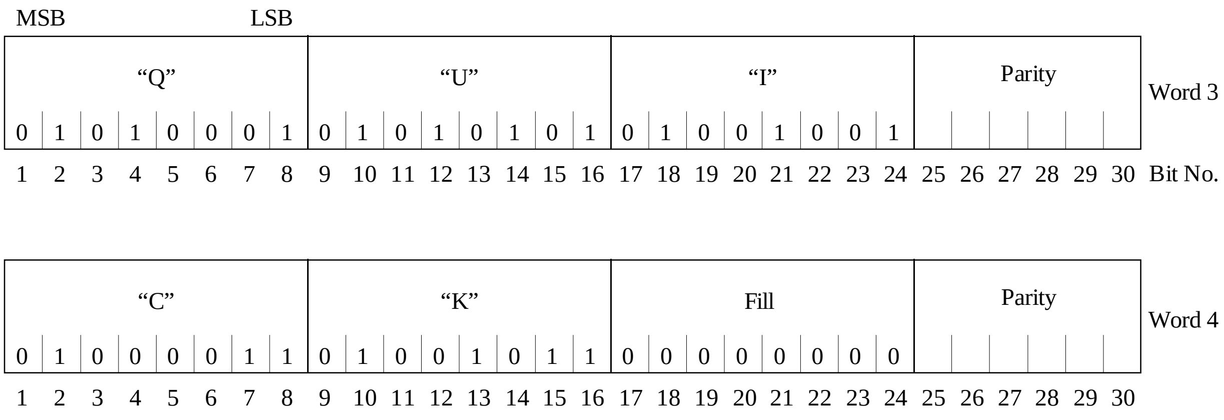


FIGURE 6

Type 16 message format
Special message (GPS)



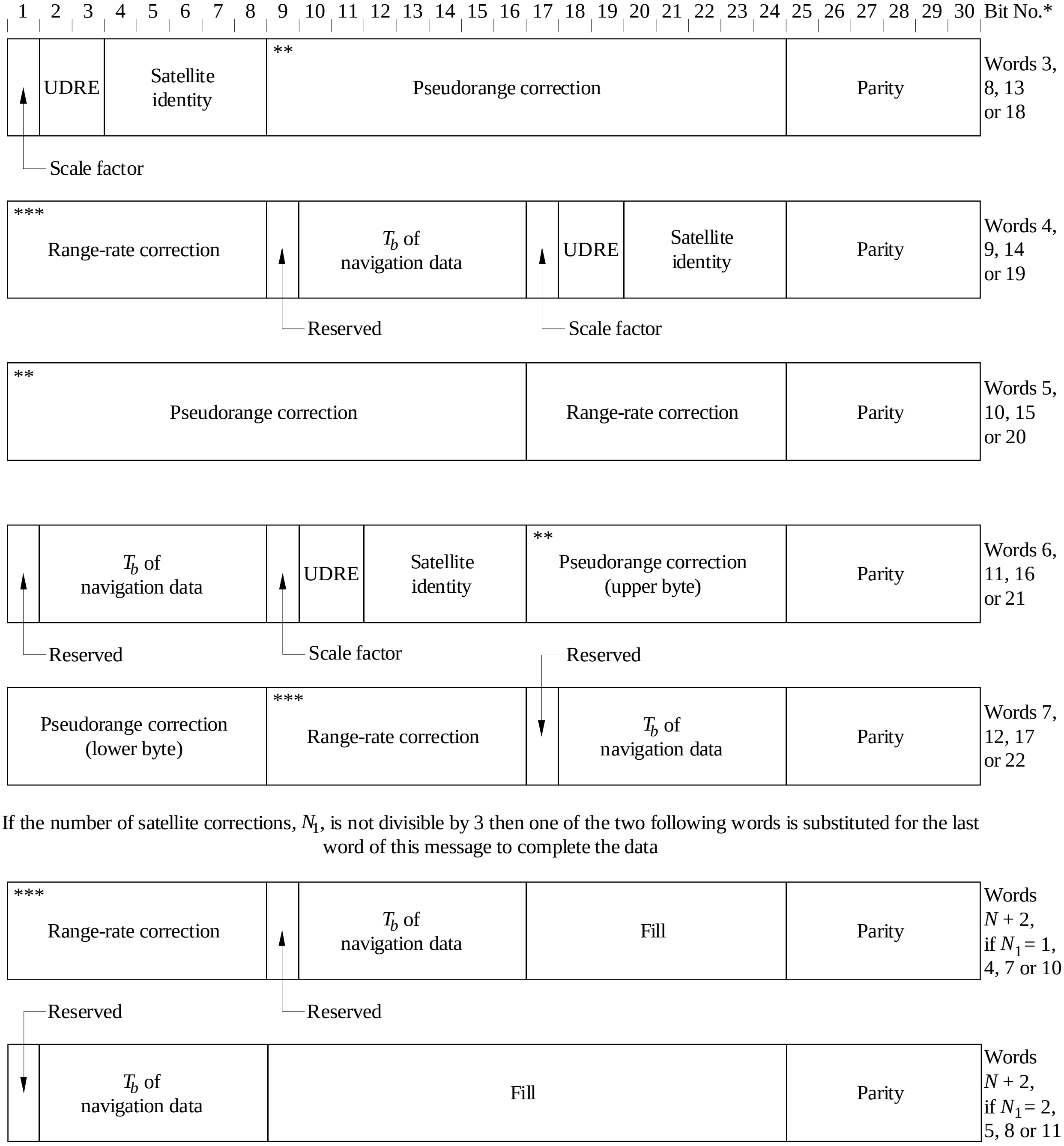
MSB: most significant bit
LSB: least significant bit

Note 1 – This figure shows how the word "quick" would look as a Type 16 message.
Note 2 – Type 16 message shall be broadcast in English. In addition, the service provider may also broadcast in another language.

D06

FIGURE 7

Type 31 and 34** message formats**
Differential GLONASS corrections



UDRE: user differential range error.

* As received.

** Binary 1000 0000 0000 0000 indicates a problem and user equipment should immediately stop using this satellite.

*** Binary 1000 0000 indicates a problem and user equipment should immediately stop using this satellite.

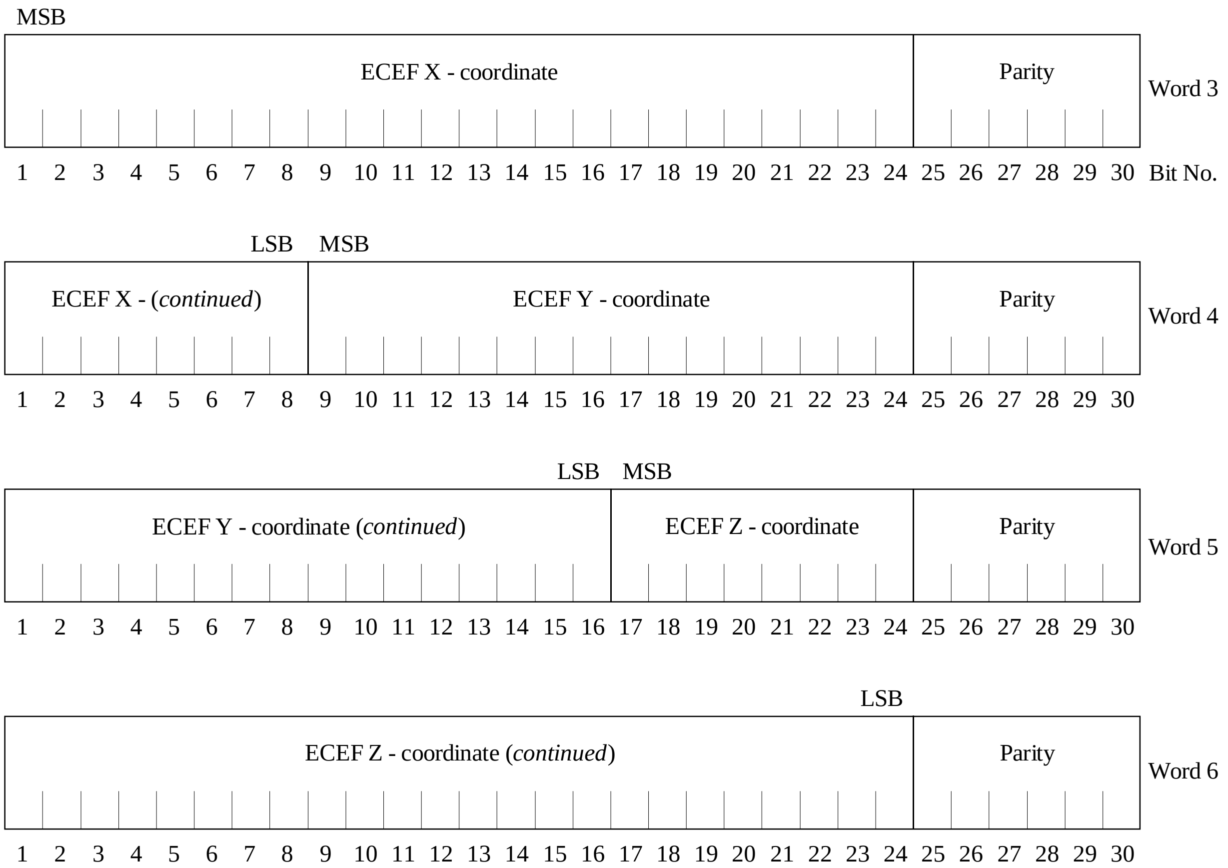
**** Type 34 message with $N = 0$ or $N = 1$ shall be used like DGPS Type 6 message as transmission fill.

Note 1 – In Type 31 messages the data from all satellites in view are transmitted. In Type 34 messages only the data from a subset of satellites are transmitted.

D07

FIGURE 8

Type 32 message format
Reference station parameters (GLONASS)



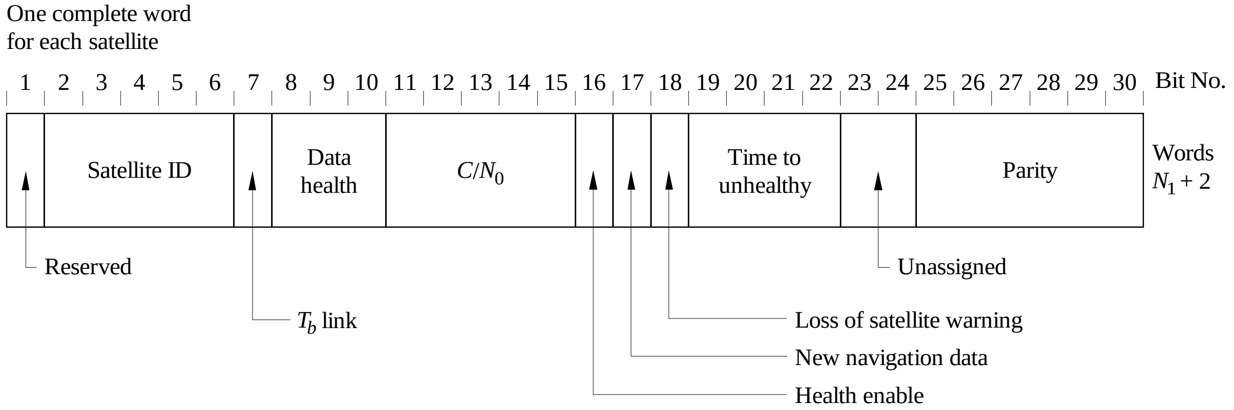
MSB: most significant bit
LSB: least significant bit
ECEF: Earth-centred, Earth-fixed, SGS-90, unless otherwise specified by service provider

D08

FIGURE 9

Type 33 message format
Constellation health (GLONASS)

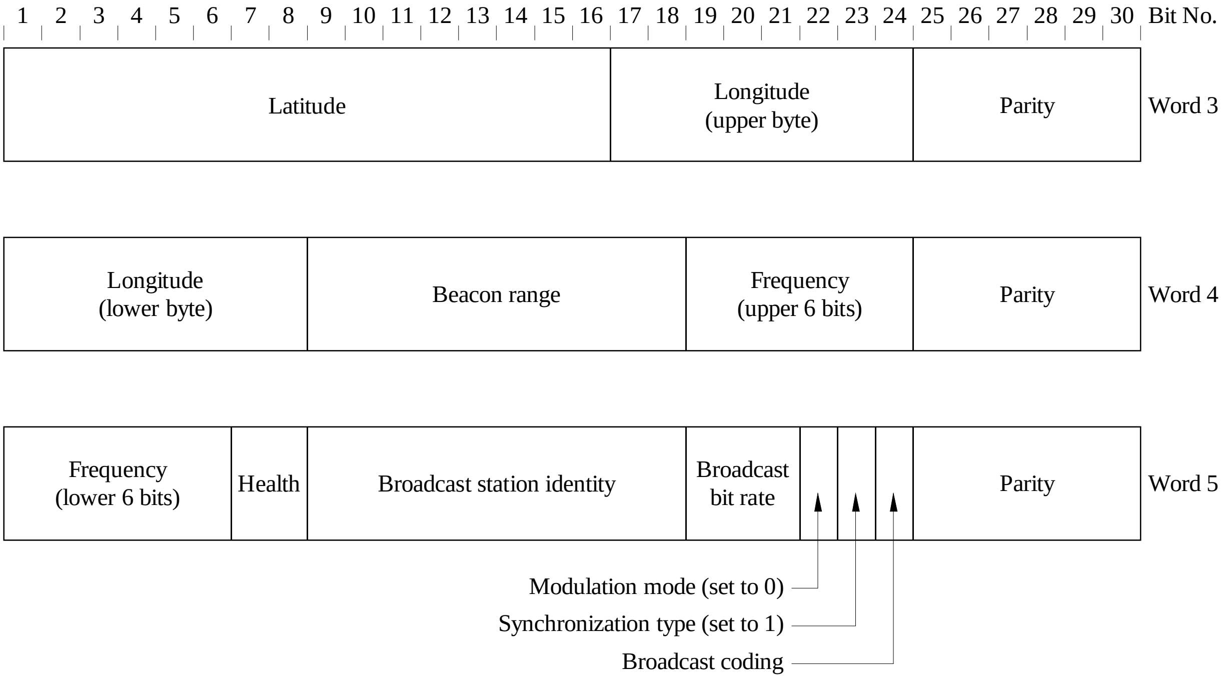
(see Table 2)



D09

FIGURE 10

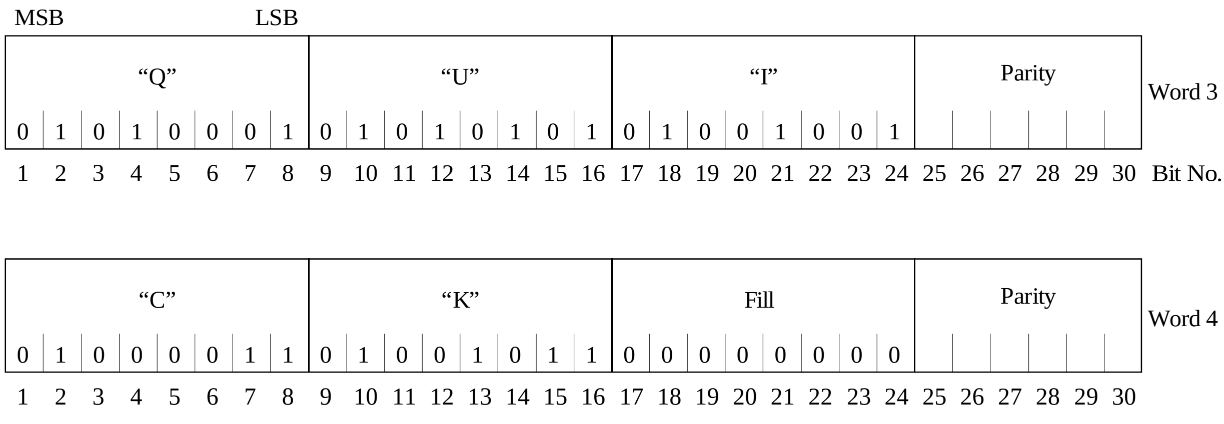
Type 35 message format
Beacon almanac (GLONASS)



D10

FIGURE 11

Type 36 message format
Special message (GLONASS)



MSB: most significant bit
LSB: least significant bit

Note 1 – This figure shows how the word "quick" would look as a Type 36 message.
Note 2 – Messages Type 36 shall be broadcast in English. In addition, the service provider may also broadcast in another language.

D11

1.4 Where Type 9 or Type 34 messages are transmitted in place of Type 1 or Type 31 messages respectively, an equal number of corrections shall be transmitted for each satellite for which corrections are calculated.

1.5 The transmission of differential data is continuous, synchronous and the most significant bit first.

1.6 The data transmission rate is selectable from 25 (GLONASS only), 50, 100 and 200 bit/s.

1.7 Minimum shift keying (class of emission G1D) is used. The form of modulation is 90° phase retard representing binary "0", 90° phase advance representing binary "1". The change of phase, relative to the carrier, is linear with a 1 bit duration.

1.8 In the EMA of Region 1, the maximum permitted occupied bandwidth should be 230 Hz.

1.9 The broadcast and reference station identities are in binary numbers. (The allocation of identities to each radio beacon broadcast and reference station is coordinated by IALA.)

1.10 The receiver frequency range is at least 283.5-325 kHz, selectable in 500 Hz steps.

1.11 The receiver has a dynamic range of 10 µV/m to 150 mV/m.

1.12 The receiver operates at a maximum bit error ratio of 1×10^{-3} in the presence of Gaussian noise at a signal-to-noise ratio of 7 dB in the occupied bandwidth.

1.13 Partially decoded Type 9 or Type 34 messages can be utilized if both words which contain the corrections for a given satellite have passed parity and no previous words in the message have failed parity.

1.14 The receiver has adequate selectivity and frequency stability to operate with transmissions 500 Hz apart having frequency tolerances of ± 2 Hz and protection ratios given in Table 3.

1.15 Where serial data ports are provided, these are to International Electrotechnical Commission (IEC) standards IEC Publication 1162 (Digital Interfaces; Navigational and Radiocommunications equipment on board ships).

1.16 The user equipment gives a warning indication of any loss of a valid navigation solution.

1.17 Where automatic frequency selection is provided in the receiver, it will be capable of receiving, storing and utilizing beacon almanac information from Type 7 and Type 35 messages.

2 Protection ratios

The protection ratios to be applied are as in Table 3.

3 Definitions

3.1 "Modified" Z-count

The Z-count represents the reference time for the differential data messages. The Z-count begins at 0, at the beginning of each hour in GPS or GLONASS time and ranges to a maximum value of 3 599.4 s, with a resolution of 0.6 s. It is used to compute the GPS time or GLONASS time of the corrections, in the same manner as other time calculations are made in the user's receivers.

3.2 Sequence number

The sequence number increments by one with each header and may be used to aid in synchronization.

TABLE 3

Protection ratios

Frequency separation between wanted and interfering signal (kHz)	Protection ratio (dB)			
Wanted	Radio beacon[1] (A1A)	Differential (G1D)	Differential (G1D)	Radio beacon[1] (A1A)
Interfering	Differential (G1D)	Radio beacon (A1A)	Differential (G1D)	Radio beacon (A1A)
0	15	15	15	15
0.5	–39	–25	–22	–39
1.0	–60	– 45	–36	–60
1.5	–60	–50	– 42	–60
2.0	–	–55	– 47	–

(1) Applicable to radio beacons in the European maritime area under the 1985 Geneva Agreement.

3.3 Issue of data (GPS)

The issue of data (IOD) as broadcast by the reference station is the value in the GPS navigational messages which corresponds to the GPS ephemeris data used to compute corrections. This is a key to ensure that the user equipment calculations and reference station corrections are based on the same set of broadcast orbital and clock parameters.

3.4 Scale factor

Two states of the scale factor for pseudorange corrections may be used and these are defined in Table 4. The rationale for the two-level scale factor is to maintain a high degree of precision most of the time, and the ability to increase the range of the corrections on those rare occasions when it is needed.

TABLE 4

Scale factor

Code	No.	Indication
0	(0)	Scale factor for pseudorange correction is 0.02 m and for range rate correction is 0.002 m/s
1	(1)	Scale factor for pseudorange correction is 0.32 m and for range rate correction is 0.032 m/s

3.5 User differential range error (UDRE)

An estimate of the root-mean-square error in the differential pseudorange correction. It is influenced by such factors as satellite signal-to-noise ratio, multipath effects and data smoothing. Table 5 defines the format for the UDRE field.

TABLE 5

User differential range error (UDRE)

Code	No.	1 σ differential error (m)
00	(0)	≤ 1
01	(1)	> 1 and ≤ 4
10	(2)	> 4 and ≤ 8
11	(3)	> 8

3.6 Earth-centred earth fixed coordination system

WGS 84 is the coordinate system used for GPS. Reference stations may however, be located in a regional system (such as NAD 83 in the United States of America). SGS 90 is the coordinate system used for GLONASS and for differential GLONASS reference stations.

3.7 T_b of navigation data (GLONASS)

The time within the current 24 h period by UTC(SU), which includes the operational information transmitted in the frame.

3.8 Special message

Type 16 and 36 messages are formatted with ASCII characters and shall be broadcast in English. In addition other languages can be broadcast by the service provider.

3.9 Message scheduling

Table 6 contains the message schedule for transmissions of DGPS corrections and Table 7 contains the message schedule for the transmission of DGPS and DGLONASS corrections when they are broadcast from the same radio beacon station.

TABLE 6

DGPS service

Type	Rate
9 or 1	Should be broadcast as often as possible
3	Should be broadcast at least twice every hour and after any change in reference station location
5	Should be broadcast at 5 min past the hour and every 15 min thereafter
6	Should be broadcast as required
7	Should be broadcast at 15 min intervals and after any change in broadcast station data. The message should include data on adjacent beacons
16	Should be broadcast as required

TABLE 7

Combined DGPS/DGLONASS

GPS		GLONASS	
Type	Rate	Type	Rate
9 or 1	Should be broadcast as often as possible (approximately every 15-20 s)	34 ($N > 1$) or 31	Should be broadcast every 50-60 s
3	Should be broadcast at 15 min and 5 min past each hour	32	Should be broadcast at 15 + 1 min and 45 + 1 min past each hour
5	Should be broadcast at 5 min past each hour and every 15 min thereafter	33	Should be broadcast at 5 + 1 min past each hour and every 15 min thereafter
6	Should be broadcast as required	34 ($N = 0$ or $N = 1$)	Should be broadcast as required
7	Should be broadcast at 7 min past the hour and every 15 min thereafter	35	Should be broadcast at 7 + 1 min past the hour and every 15 min thereafter
16	Should be broadcast as required	36	Should be broadcast as required