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(12) **United States Patent**
Rao et al.

(10) **Patent No.: US 10,436,911 B2**
(45) **Date of Patent: Oct. 8, 2019**

(54) **NAVIGATION DATA CONFIGURATION FOR OPTIMAL TIME TO FIRST FIX**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 268 days.

(21) Appl. No.: **15/462,925**

(22) Filed: **Mar. 20, 2017**

(65) **Prior Publication Data**

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Related U.S. Application Data

(62) Division of application No. 14/018,443, filed on Sep. 5, 2013, now Pat. No. 9,638,803.

(30) **Foreign Application Priority Data**

May 6, 2013 (IN) 2011/CHE/2013

(51) **Int. Cl.**
G01S 19/05 (2010.01)

(52) **U.S. Cl.**
CPC ***G01S 19/05*** (2013.01)

(58) **Field of Classification Search**
CPC G01S 19/05
USPC 342/357.42
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

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Rao et al., "Proposed LOS Signal Design for IRNSS to Reduce TTFF in a Signal Frequency Receiver", GNSS Signals 2011, Session: Signal Design 2, Toulouse, Dec. 8-9, 2011 (Year: 2011).*
N. Neelakantan, "Overview of Indian Satellite Navigation Programme", Oct. 18, 2010, India Space Research Organization, www.oosa.unvienna.org/pdf/icq/2010/ICG5/18october/05.pdf (Year: 2010).*

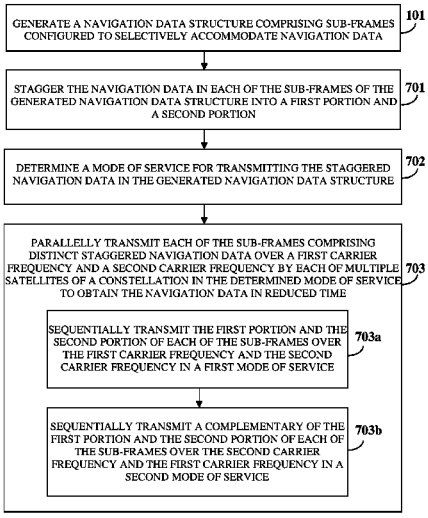
* cited by examiner

Primary Examiner — Frank J McGue
(74) *Attorney, Agent, or Firm* — Ashok Tankha

(57) **ABSTRACT**

A method and a system for reducing time to first fix (TTFF) in a satellite navigation receiver generate a navigation data structure including three sub-frames. A first sub-frame and a second sub-frame accommodate selective ephemeris data. The third sub-frame accommodates a text message including almanac data optionally, ionospheric data, coordinated universal time (UTC) data, textual data optionally, and any combination thereof. A signal generation system (SGS) in the system selectively groups the almanac data, the ionospheric data, and the UTC data, and selectively transmits the navigation data with the almanac data or free of the almanac data in the navigation data structure to the satellite navigation receiver. The signal generation system also staggers the navigation data in each sub-frame into a first portion and a second portion for parallelly transmitting the navigation data over a first carrier frequency and a second carrier frequency in reduced time.

3 Claims, 17 Drawing Sheets



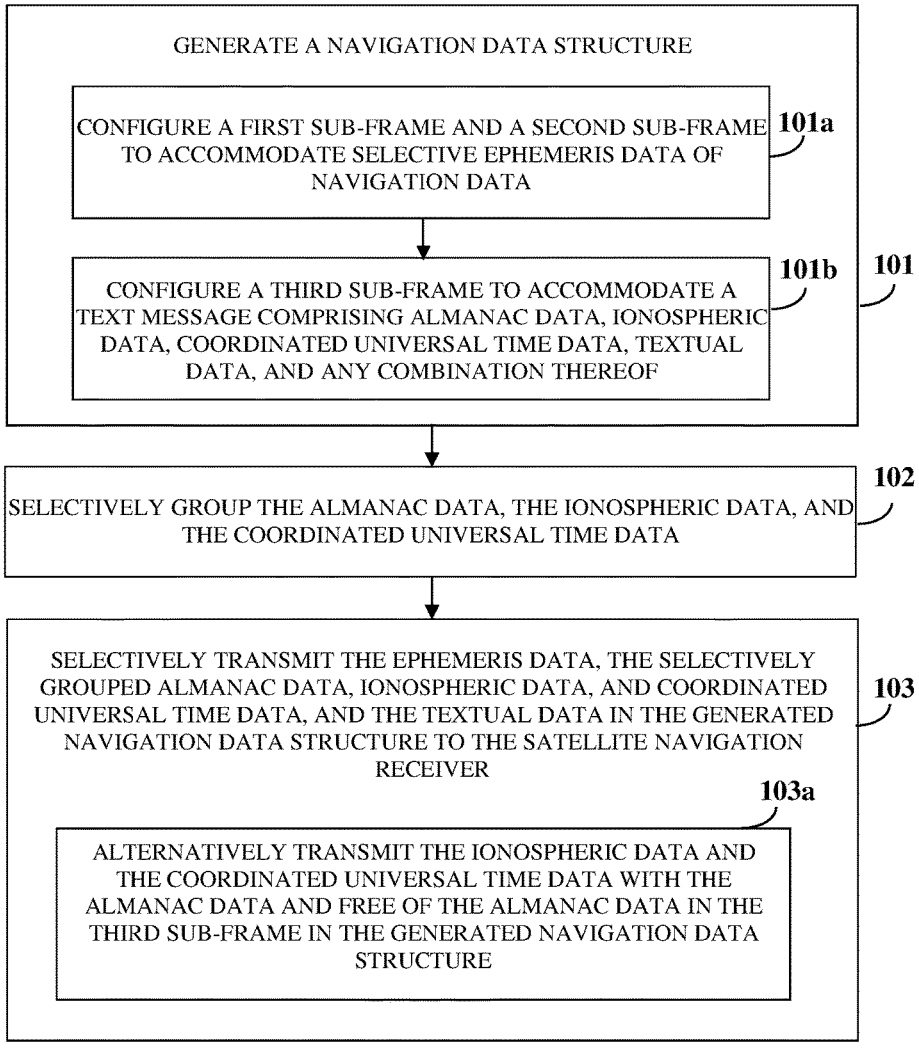

GENERATE A NAVIGATION DATA STRUCTURE
CONFIGURE A FIRST SUB-FRAME AND A SECOND SUB-FRAME TO ACCOMMODATE SELECTIVE EPHEMERIS DATA OF NAVIGATION DATA
101a
CONFIGURE A THIRD SUB-FRAME TO ACCOMMODATE A TEXT MESSAGE COMPRISING ALMANAC DATA, IONOSPHERIC DATA, COORDINATED UNIVERSAL TIME DATA, TEXTUAL DATA, AND ANY COMBINATION THEREOF
101b
101
SELECTIVELY GROUP THE ALMANAC DATA, THE IONOSPHERIC DATA, AND THE COORDINATED UNIVERSAL TIME DATA
102
SELECTIVELY TRANSMIT THE EPHEMERIS DATA, THE SELECTIVELY GROUPED ALMANAC DATA, IONOSPHERIC DATA, AND COORDINATED UNIVERSAL TIME DATA, AND THE TEXTUAL DATA IN THE GENERATED NAVIGATION DATA STRUCTURE TO THE SATELLITE NAVIGATION RECEIVER
103
103a
ALTERNATIVELY TRANSMIT THE IONOSPHERIC DATA AND THE COORDINATED UNIVERSAL TIME DATA WITH THE ALMANAC DATA AND FREE OF THE ALMANAC DATA IN THE THIRD SUB-FRAME IN THE GENERATED NAVIGATION DATA STRUCTURE

FIG. 1

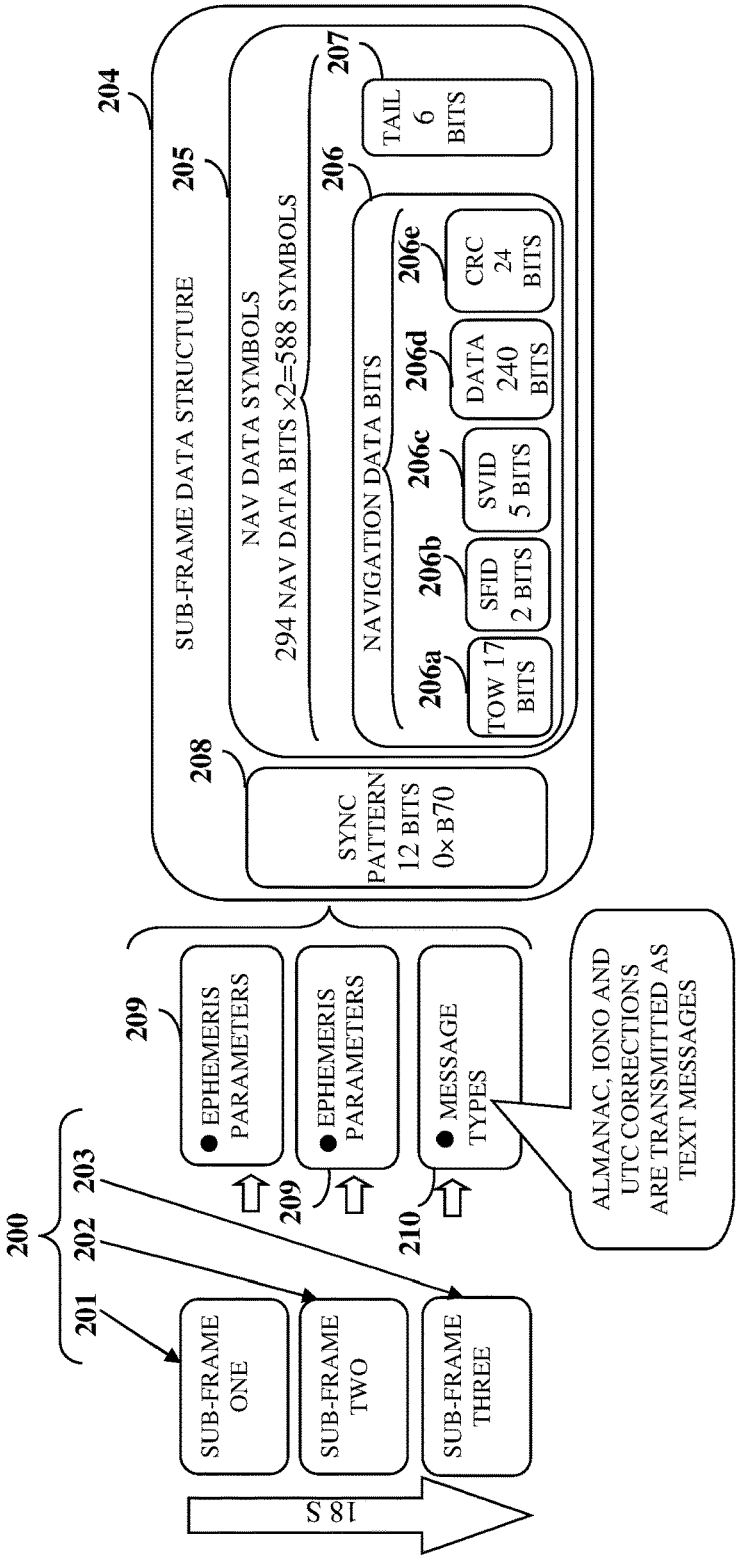

200
201
202
203
SUB-FRAME ONE
SUB-FRAME TWO
SUB-FRAME THREE
18 S
209
210
EPHEMERIS PARAMETERS
EPHEMERIS PARAMETERS
MESSAGE TYPES
ALMANAC, IONO AND UTC CORRECTIONS ARE TRANSMITTED AS TEXT MESSAGES
204
SUB-FRAME DATA STRUCTURE
205
NAV DATA SYMBOLS
294 NAV DATA BITS x2=588 SYMBOLS
206
NAVIGATION DATA BITS
206a
206b
206c
206d
206e
TOW 17 BITS
SFID 2 BITS
SVID 5 BITS
DATA 240 BITS
CRC 24 BITS
207
TAIL 6 BITS
208
SYNC PATTERN 12 BITS 0x B70

FIG. 2

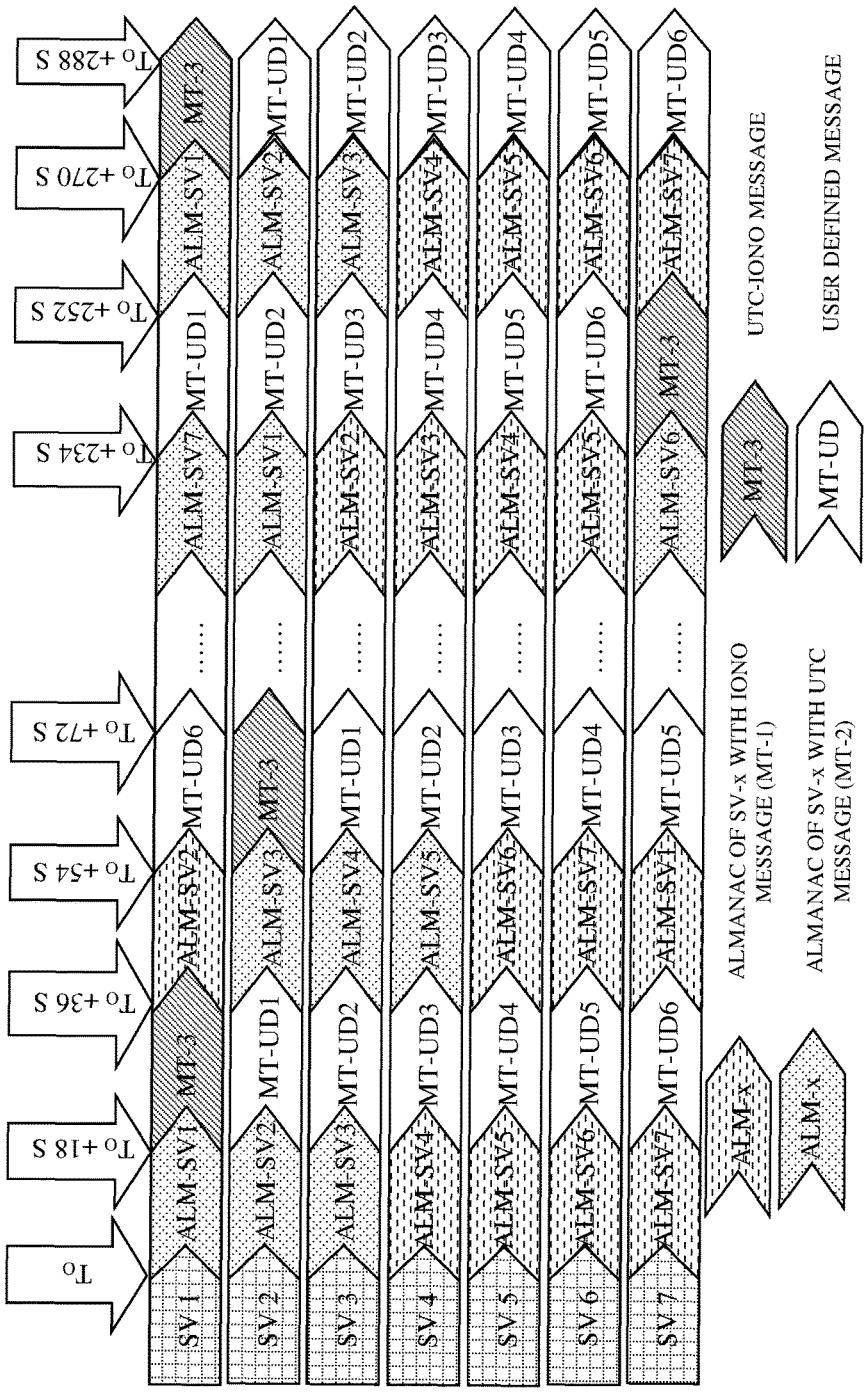

To
To +18 S
To +36 S
To +54 S
To +72 S
To +234 S
To +252 S
To +270 S
To +288 S
SV 1
SV 2
SV 3
SV 4
SV 5
SV 6
SV 7
ALM-SV1
ALM-SV2
ALM-SV3
ALM-SV4
ALM-SV5
ALM-SV6
ALM-SV7
MT-3
MT-UD1
MT-UD2
MT-UD3
MT-UD4
MT-UD5
MT-UD6
.....
ALM-x
ALMANAC OF SV-x WITH IONO MESSAGE (MT-1)
ALMANAC OF SV-x WITH UTC MESSAGE (MT-2)
UTC-IONO MESSAGE
USER DEFINED MESSAGE

FIG. 3

MESSAGE TYPE	DESCRIPTION	SATELLITE ID	RATE (S)
00	RESERVED	--	---
01	ALMANAC-IONO	IN ALL SATELLITES STAGGERED	(T0 + 18) * N^{+}, WHERE N = 1, 3 …33599
02	ALMANAC-UTC	IN ALL SATELLITES STAGGERED	(T0 + 18) * N, WHERE N = 1, 3 …33599
03	IONO-UTC	ONE SATELLITE, STAGGERED	(T0 + 18) * N, WHERE N = 2, 4 …33600
04 – 63	ANY USER DATA	SATELLITES, STAGGERED (CYCLIC)	(T0 + 18) * N, WHERE N = 2, 4 …33600

FIG. 4

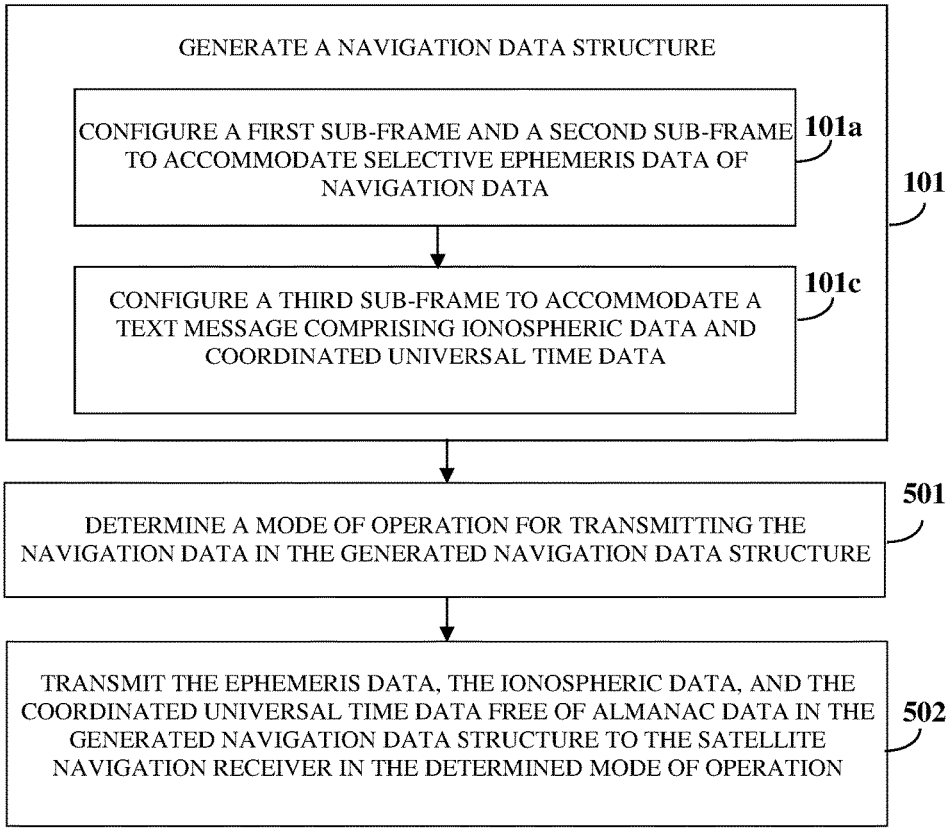

GENERATE A NAVIGATION DATA STRUCTURE
CONFIGURE A FIRST SUB-FRAME AND A SECOND SUB-FRAME TO ACCOMMODATE SELECTIVE EPHEMERIS DATA OF NAVIGATION DATA
101a
CONFIGURE A THIRD SUB-FRAME TO ACCOMMODATE A TEXT MESSAGE COMPRISING IONOSPHERIC DATA AND COORDINATED UNIVERSAL TIME DATA
101c
101
DETERMINE A MODE OF OPERATION FOR TRANSMITTING THE NAVIGATION DATA IN THE GENERATED NAVIGATION DATA STRUCTURE
501
TRANSMIT THE EPHEMERIS DATA, THE IONOSPHERIC DATA, AND THE COORDINATED UNIVERSAL TIME DATA FREE OF ALMANAC DATA IN THE GENERATED NAVIGATION DATA STRUCTURE TO THE SATELLITE NAVIGATION RECEIVER IN THE DETERMINED MODE OF OPERATION
502

FIG. 5

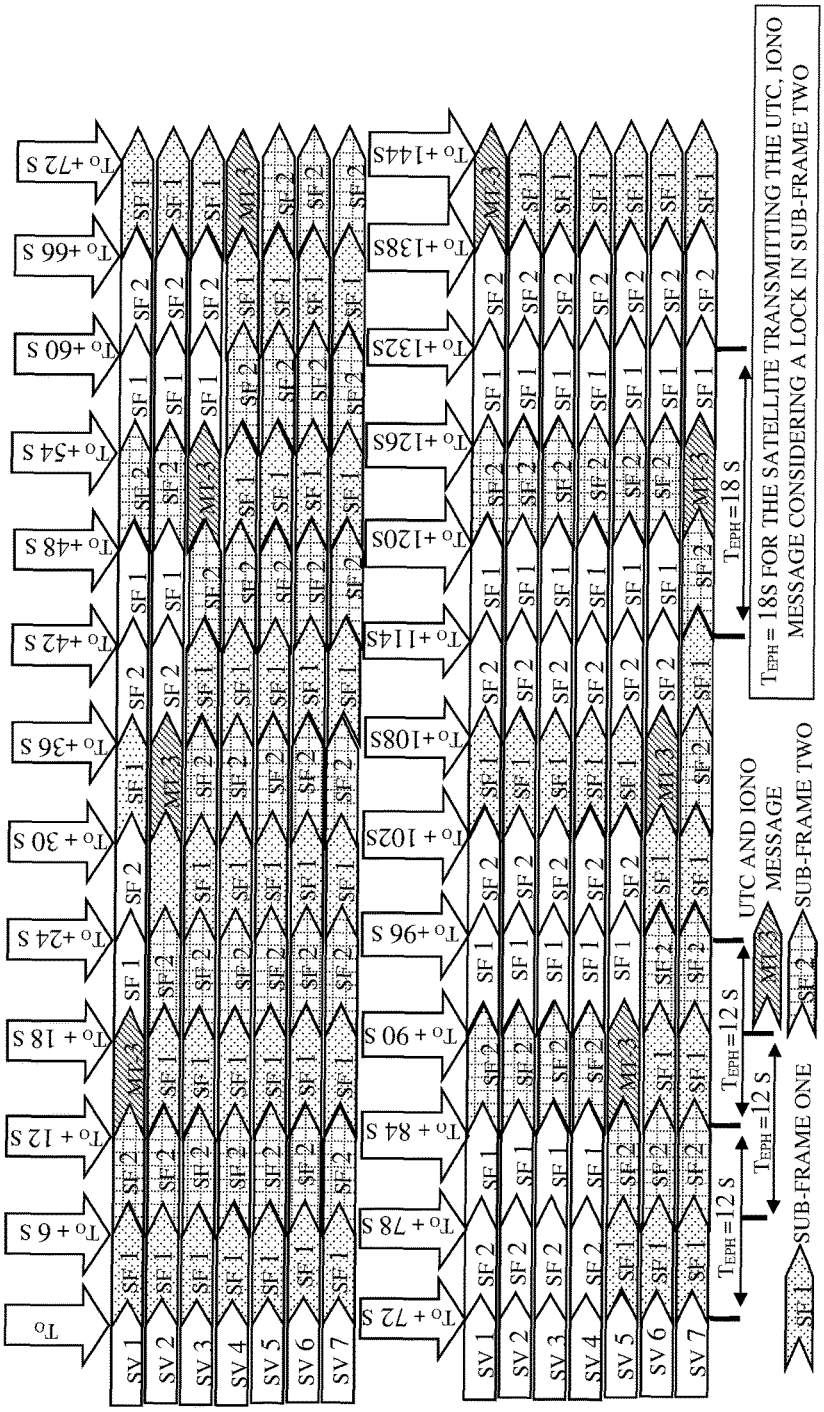

SV 1
SV 2
SV 3
SV 4
SV 5
SV 6
SV 7
To
To + 6 S
To + 12 S
To + 18 S
To +24 S
To + 30 S
To +36 S
To +42 S
To +48 S
To +54 S
To +60 S
To +66 S
To +72 S
To + 72 S
To + 78 S
To + 84 S
To + 90 S
To +96 S
To + 102S
To+108S
To +114S
To +120S
To +126S
To +132S
To +138S
To +144S
SF 1
SF 2
MT 3
TEPH=12 S
TEPH=18 S
UTC AND IONO MESSAGE SUB-FRAME TWO
TEPH = 18S FOR THE SATELLITE TRANSMITTING THE UTC, IONO MESSAGE CONSIDERING A LOCK IN SUB-FRAME TWO
SUB-FRAME ONE

FIG. 6

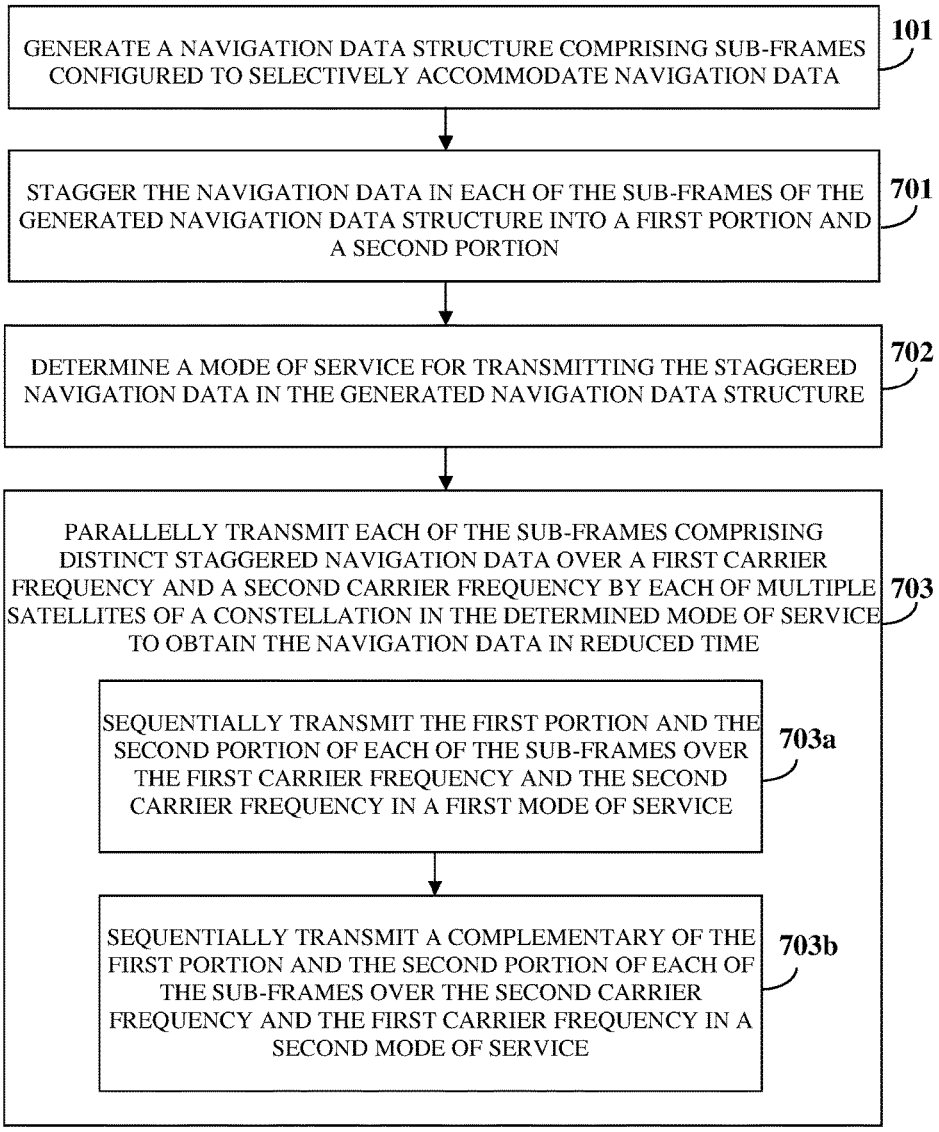

GENERATE A NAVIGATION DATA STRUCTURE COMPRISING SUB-FRAMES CONFIGURED TO SELECTIVELY ACCOMMODATE NAVIGATION DATA
101
STAGGER THE NAVIGATION DATA IN EACH OF THE SUB-FRAMES OF THE GENERATED NAVIGATION DATA STRUCTURE INTO A FIRST PORTION AND A SECOND PORTION
701
DETERMINE A MODE OF SERVICE FOR TRANSMITTING THE STAGGERED NAVIGATION DATA IN THE GENERATED NAVIGATION DATA STRUCTURE
702
PARALLELLY TRANSMIT EACH OF THE SUB-FRAMES COMPRISING DISTINCT STAGGERED NAVIGATION DATA OVER A FIRST CARRIER FREQUENCY AND A SECOND CARRIER FREQUENCY BY EACH OF MULTIPLE SATELLITES OF A CONSTELLATION IN THE DETERMINED MODE OF SERVICE TO OBTAIN THE NAVIGATION DATA IN REDUCED TIME
703
SEQUENTIALLY TRANSMIT THE FIRST PORTION AND THE SECOND PORTION OF EACH OF THE SUB-FRAMES OVER THE FIRST CARRIER FREQUENCY AND THE SECOND CARRIER FREQUENCY IN A FIRST MODE OF SERVICE
703a
SEQUENTIALLY TRANSMIT A COMPLEMENTARY OF THE FIRST PORTION AND THE SECOND PORTION OF EACH OF THE SUB-FRAMES OVER THE SECOND CARRIER FREQUENCY AND THE FIRST CARRIER FREQUENCY IN A SECOND MODE OF SERVICE
703b

FIG. 7

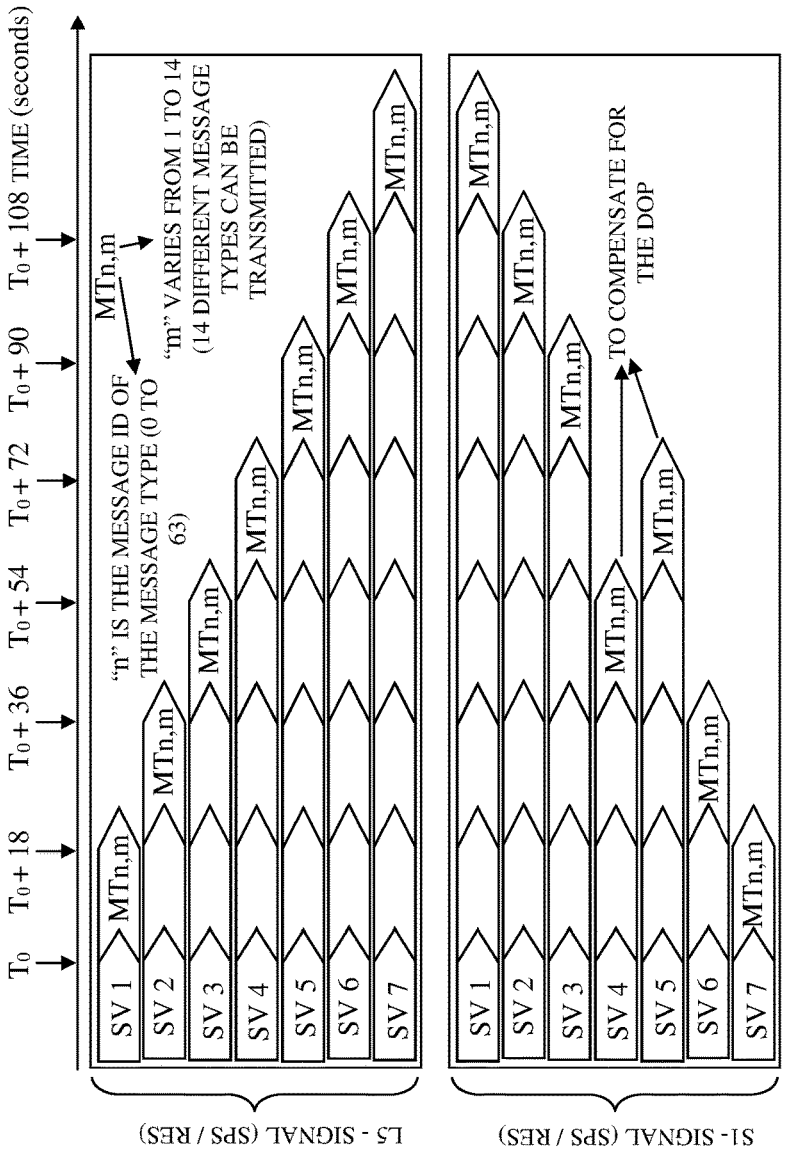

T0
T0 + 18
T0 + 36
T0 + 54
T0 + 72
T0 + 90
T0 + 108 TIME (seconds)
"n" IS THE MESSAGE ID OF THE MESSAGE TYPE (0 TO 63)
"m" VARIES FROM 1 TO 14 (14 DIFFERENT MESSAGE TYPES CAN BE TRANSMITTED)
TO COMPENSATE FOR THE DOP
MTn,m
SV 1
SV 2
SV 3
SV 4
SV 5
SV 6
SV 7
L5 - SIGNAL (SPS / RES)
S1- SIGNAL (SPS / RES)

FIG. 8

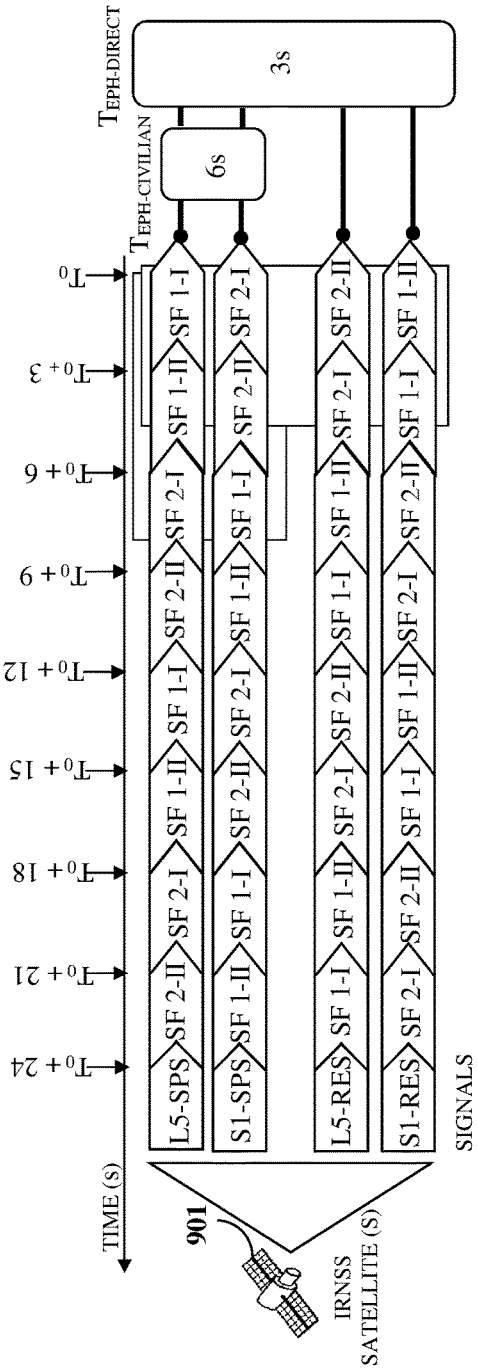

IRNSS SATELLITE (S)
901
TIME (s)
SIGNALS
L5-SPS
S1-SPS
L5-RES
S1-RES
SF 2-II
SF 2-I
SF 1-II
SF 1-I
T_0
T_0 + 3
T_0 + 6
T_0 + 9
T_0 + 12
T_0 + 15
T_0 + 18
T_0 + 21
T_0 + 24
$T_{EPH-CIVILIAN}$
$T_{EPH-DIRECT}$
6s
3s

FIG. 9A

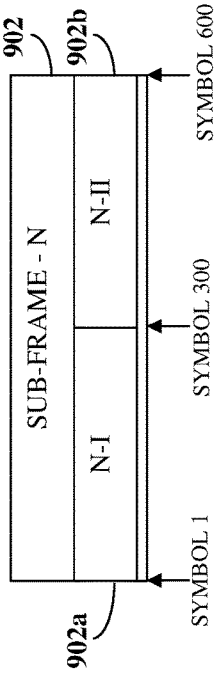

902
902b
902a
SUB-FRAME - N
N-I
N-II
SYMBOL 1
SYMBOL 300
SYMBOL 600

FIG. 9B

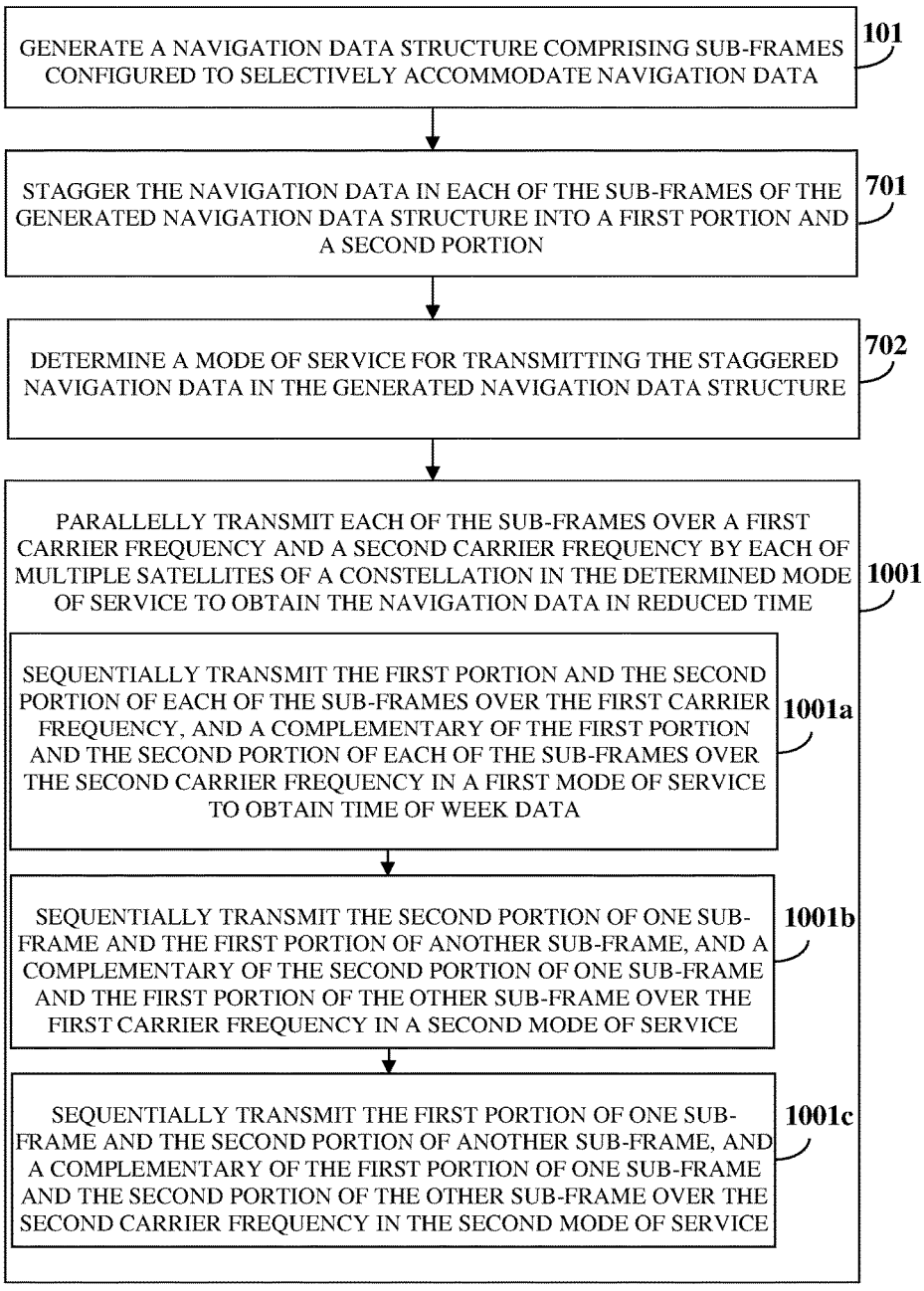

GENERATE A NAVIGATION DATA STRUCTURE COMPRISING SUB-FRAMES CONFIGURED TO SELECTIVELY ACCOMMODATE NAVIGATION DATA
101
STAGGER THE NAVIGATION DATA IN EACH OF THE SUB-FRAMES OF THE GENERATED NAVIGATION DATA STRUCTURE INTO A FIRST PORTION AND A SECOND PORTION
701
DETERMINE A MODE OF SERVICE FOR TRANSMITTING THE STAGGERED NAVIGATION DATA IN THE GENERATED NAVIGATION DATA STRUCTURE
702
PARALLELLY TRANSMIT EACH OF THE SUB-FRAMES OVER A FIRST CARRIER FREQUENCY AND A SECOND CARRIER FREQUENCY BY EACH OF MULTIPLE SATELLITES OF A CONSTELLATION IN THE DETERMINED MODE OF SERVICE TO OBTAIN THE NAVIGATION DATA IN REDUCED TIME
1001
SEQUENTIALLY TRANSMIT THE FIRST PORTION AND THE SECOND PORTION OF EACH OF THE SUB-FRAMES OVER THE FIRST CARRIER FREQUENCY, AND A COMPLEMENTARY OF THE FIRST PORTION AND THE SECOND PORTION OF EACH OF THE SUB-FRAMES OVER THE SECOND CARRIER FREQUENCY IN A FIRST MODE OF SERVICE TO OBTAIN TIME OF WEEK DATA
1001a
SEQUENTIALLY TRANSMIT THE SECOND PORTION OF ONE SUB-FRAME AND THE FIRST PORTION OF ANOTHER SUB-FRAME, AND A COMPLEMENTARY OF THE SECOND PORTION OF ONE SUB-FRAME AND THE FIRST PORTION OF THE OTHER SUB-FRAME OVER THE FIRST CARRIER FREQUENCY IN A SECOND MODE OF SERVICE
1001b
SEQUENTIALLY TRANSMIT THE FIRST PORTION OF ONE SUB-FRAME AND THE SECOND PORTION OF ANOTHER SUB-FRAME, AND A COMPLEMENTARY OF THE FIRST PORTION OF ONE SUB-FRAME AND THE SECOND PORTION OF THE OTHER SUB-FRAME OVER THE SECOND CARRIER FREQUENCY IN THE SECOND MODE OF SERVICE
1001c

FIG. 10

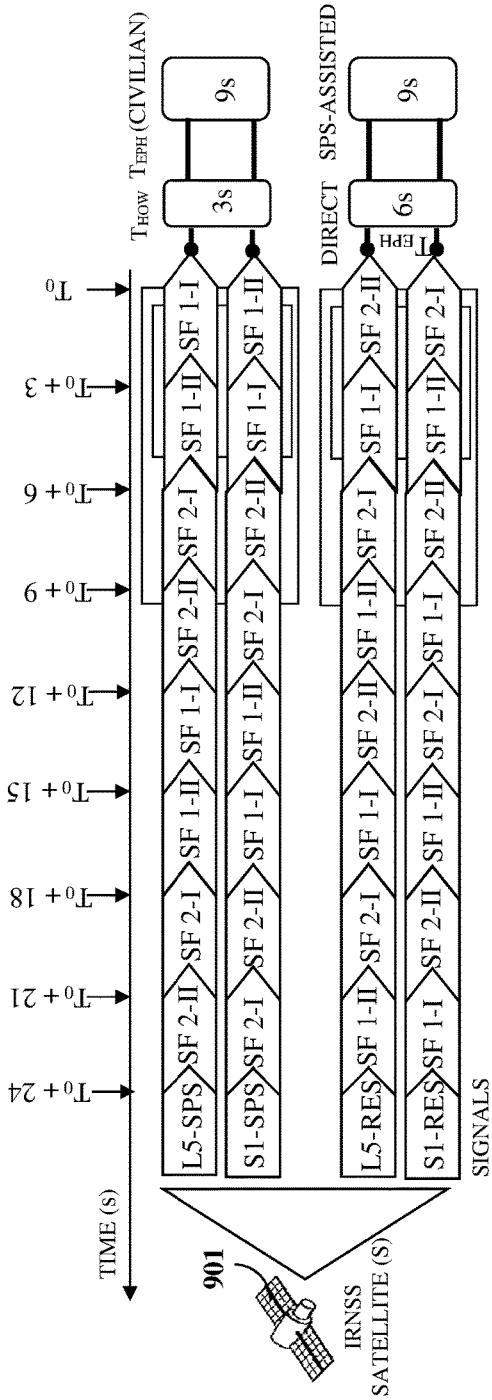


FIG. 11A

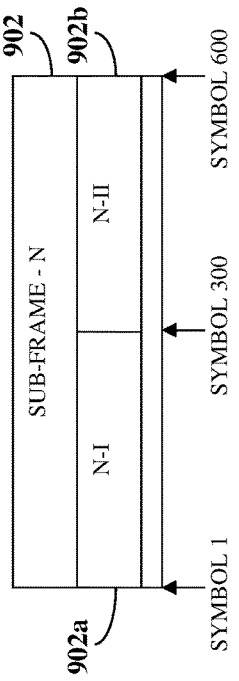


FIG. 11B

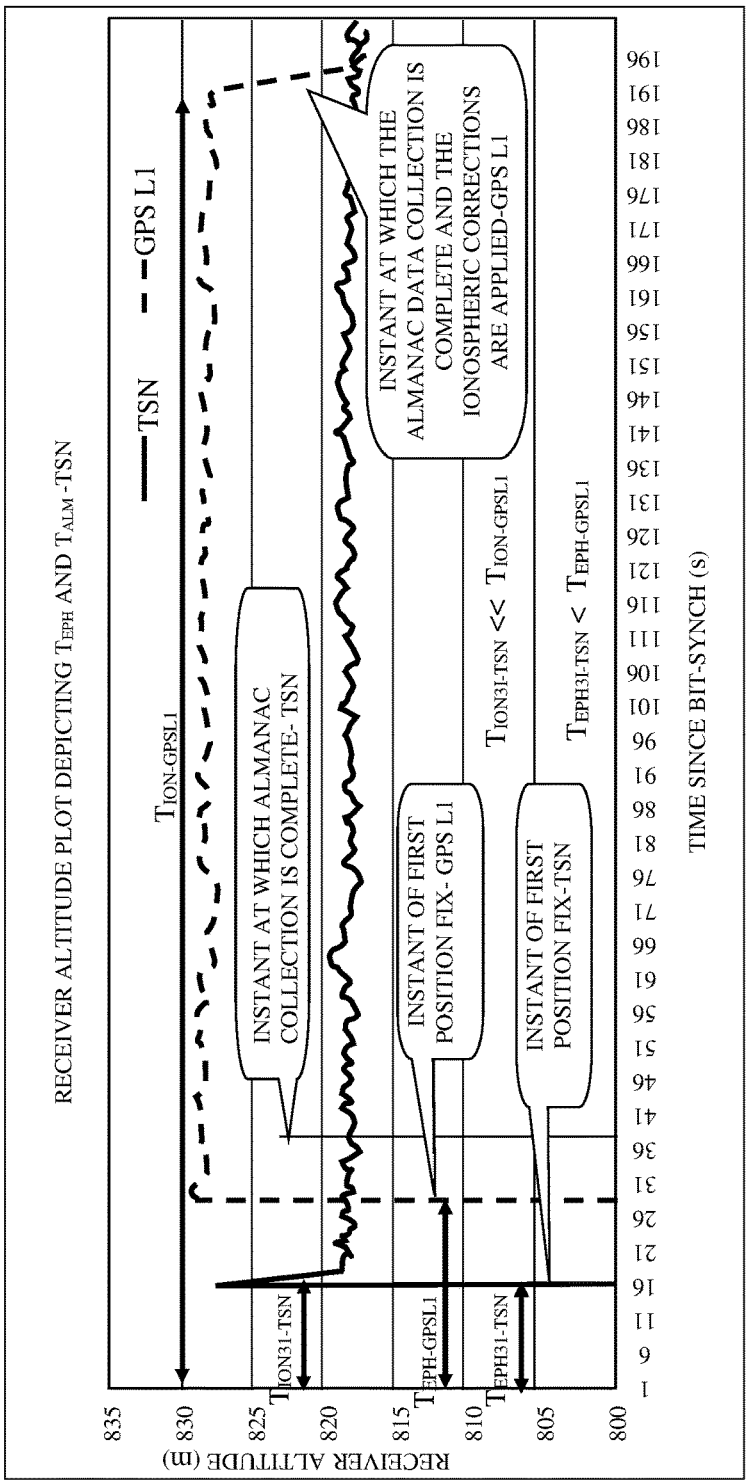

RECEIVER ALTITUDE PLOT DEPICTING T_{EPH} AND T_{ALM} -TSN
TSN
GPS L1
$T_{ION-GPSL1}$
INSTANT AT WHICH ALMANAC COLLECTION IS COMPLETE- TSN
INSTANT OF FIRST POSITION FIX- GPS L1
INSTANT OF FIRST POSITION FIX-TSN
INSTANT AT WHICH THE ALMANAC DATA COLLECTION IS COMPLETE AND THE IONOSPHERIC CORRECTIONS ARE APPLIED-GPS L1
$T_{ION31-TSN}$
$T_{EPH-GPSL1}$
$T_{EPH31-TSN}$
$T_{ION31-TSN}$ << $T_{ION-GPSL1}$
$T_{EPH31-TSN}$ < $T_{EPH-GPSL1}$
RECEIVER ALTITUDE (m)
835
830
825
820
815
810
805
800
TIME SINCE BIT-SYNCH (s)
1
6
11
16
21
26
31
36
41
46
51
56
61
66
71
76
81
86
91
96
101
106
111
116
121
126
131
136
141
146
151
156
161
166
171
176
181
186
191
196

FIG. 12

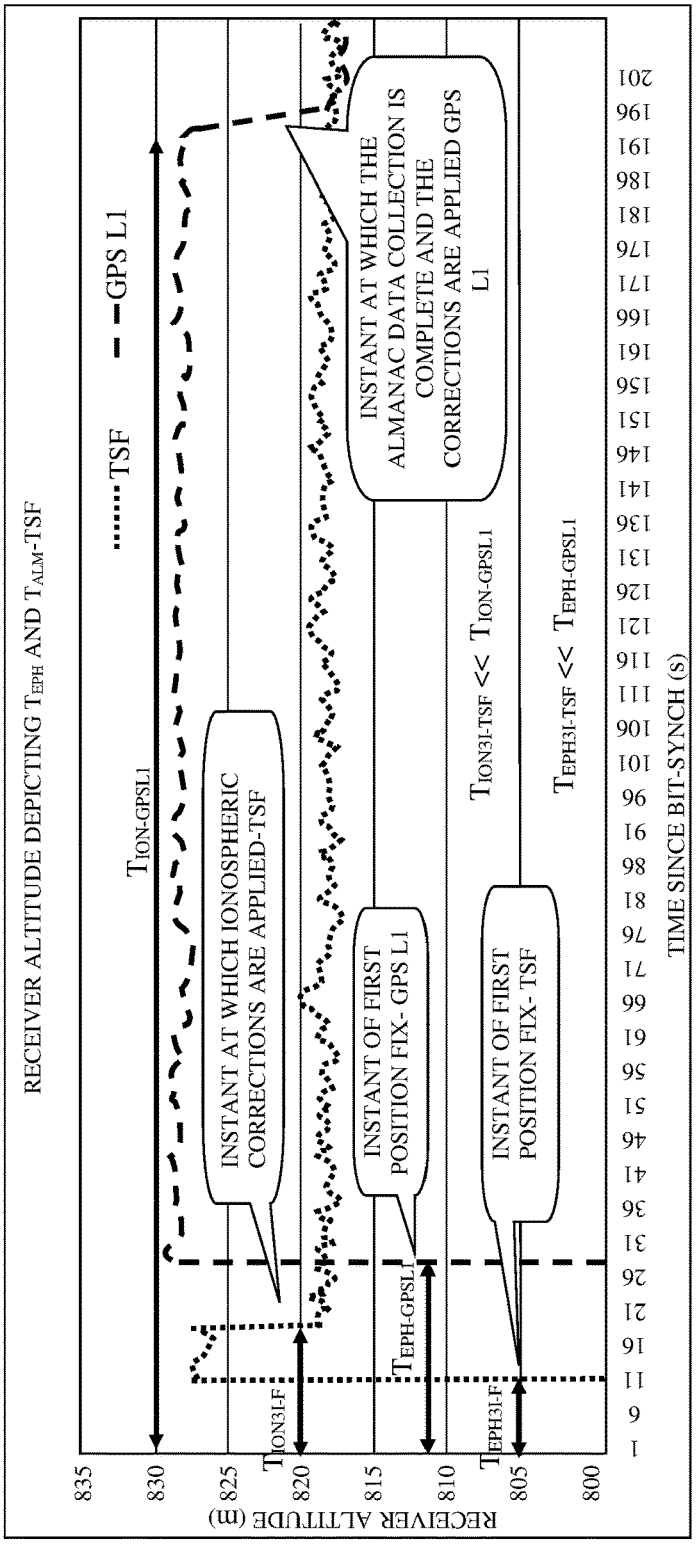

RECEIVER ALTITUDE DEPICTING T_{EPH} AND T_{ALM}-TSF
TSF
GPS L1
$T_{ION-GPSL1}$
INSTANT AT WHICH IONOSPHERIC CORRECTIONS ARE APPLIED-TSF
INSTANT OF FIRST POSITION FIX- GPS L1
INSTANT OF FIRST POSITION FIX- TSF
INSTANT AT WHICH THE ALMANAC DATA COLLECTION IS COMPLETE AND THE CORRECTIONS ARE APPLIED GPS L1
$T_{ION3I-TSF}$ << $T_{ION-GPSL1}$
$T_{EPH3I-TSF}$ << $T_{EPH-GPSL1}$
$T_{ION3I-F}$
$T_{EPH-GPSL1}$
$T_{EPH3I-F}$
RECEIVER ALTITUDE (m)
835
830
825
820
815
810
805
800
TIME SINCE BIT-SYNCH (s)
1
6
11
16
21
26
31
36
41
46
51
56
61
66
71
76
81
86
91
96
101
106
111
116
121
126
131
136
141
146
151
156
161
166
171
176
181
186
191
196
201

FIG. 13

PARAMETER	TSN	TSF
ASSUMPTION	NONE	SECONDARY PARAMETERS ARE RESTRICTED TO UTC AND IONOSPHERIC TERMS ONLY
T_{EPH}/TTFF	40% IMPROVEMENT	60% IMPROVEMENT
$T_{TEXTUAL}/T_{ALM}$	82% IMPROVEMENT	NOT APPLICABLE
GLOBAL EXTENSION OF IRNSS	POSSIBLE	POSSIBLE

FIG. 14

MODE OF OPERATION	SPS (s)	RESTRICTED (s)	DESCRIPTION
SINGLE	12	12	THE TRANSMISSION OF PRIMARY PARAMETERS IS OPTIMAL FROM EITHER THE L5 OR S1 PATH FOR A SPS USER, WHICH IS THE TTFF OF RESTRICTED USERS (ASSUMING THE DATA OF SPS AND RESTRICTED ARE THE SAME)
DUAL	6	6	THE DATA FROM THE L5/S1 PATHS EFFECTIVELY ENABLE THE SPS RECEIVER TO ACHIEVE THE MOST OPTIMAL TTFF. WITH TOW, THE RESTRICTED SERVICE ENTERS INTO MEASUREMENT MODE AND PROVIDES INSTANTANEOUS POSITIONING (WITH NAV DATA FROM SPS PATH)

FIG. 15

MODE OF OPERATION	SPS (s)	RESTRICTED (s)	DESCRIPTION/REMARKS
SINGLE	12	18	THE TRANSMISSION OF THE PRIMARY NAVIGATION DATA PARAMETERS IS IDENTICAL AND THUS TTFF FROM EITHER L5 OR S1 REMAINS THE SAME. WITH DATA BEING DIFFERENT, THE CODE DIVERSITY IS NOT APPLICABLE AND THUS WITH SPS ASSISTANCE, THE TTFF FOLLOWS RESTRICTED USERS IN A SINGLE FREQUENCY MODE.
DUAL	9	9	IN THE CIVILIAN MODE OF OPERATION, THE NAVIGATION DATA FROM L5 AND S1 WHEN PROCESSED EFFECTIVELY RESULTS IN A TTFF OF 9s. WITH HOW AVAILABLE IN 3s (STRADDLING OF THE SPS SUB-FRAMES), THE TTFF OF THE RESTRICTED USERS IN THE SPS ASSISTED MODE WITH DIFFERENT DATA IS 9s.

FIG. 16

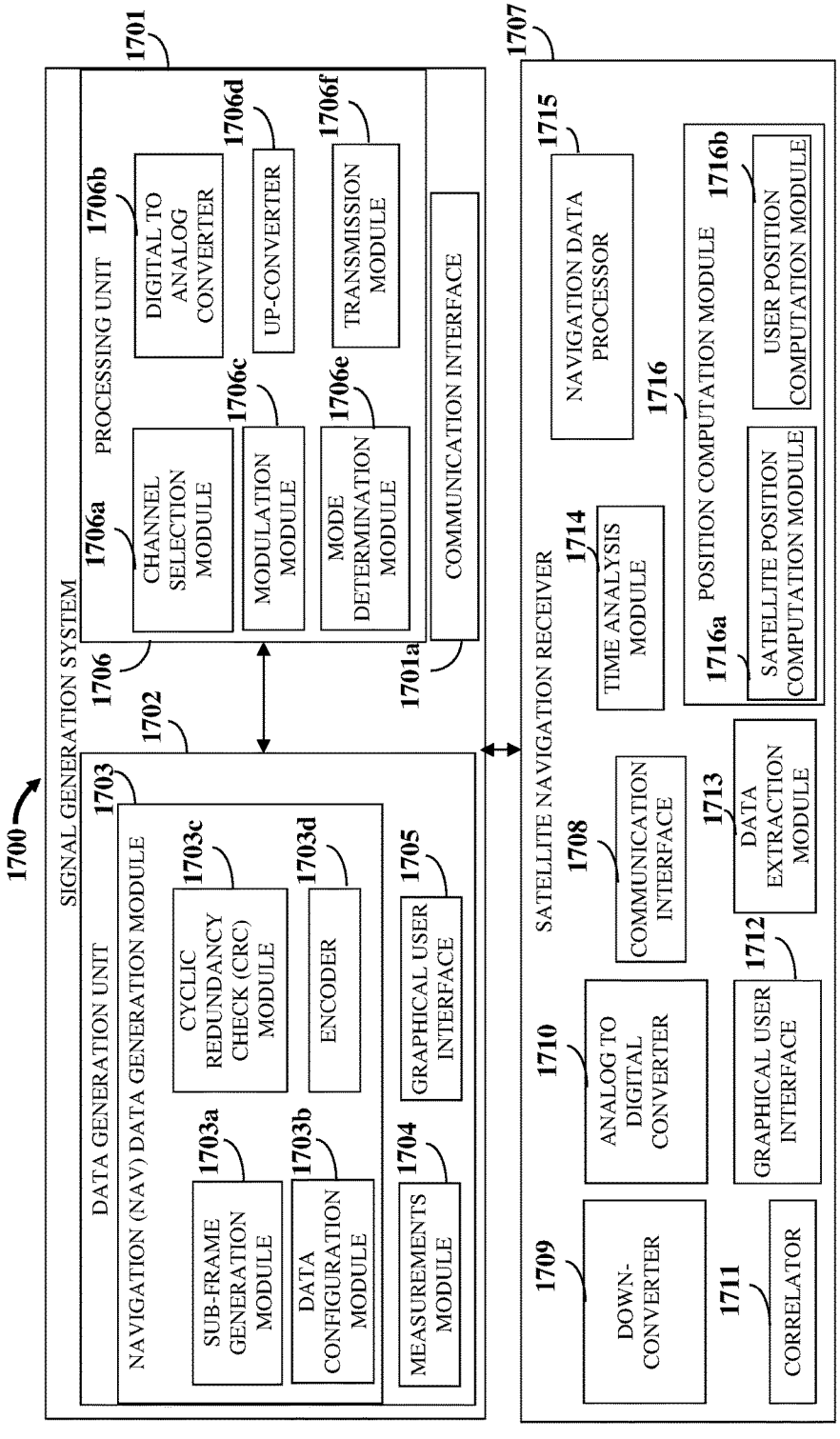

1700
SIGNAL GENERATION SYSTEM
1701
PROCESSING UNIT
1706
1706a
CHANNEL SELECTION MODULE
1706b
DIGITAL TO ANALOG CONVERTER
1706c
MODULATION MODULE
1706d
UP-CONVERTER
1706e
MODE DETERMINATION MODULE
1706f
TRANSMISSION MODULE
1701a
COMMUNICATION INTERFACE
1702
DATA GENERATION UNIT
1703
NAVIGATION (NAV) DATA GENERATION MODULE
1703a
SUB-FRAME GENERATION MODULE
1703b
DATA CONFIGURATION MODULE
1703c
CYCLIC REDUNDANCY CHECK (CRC) MODULE
1703d
ENCODER
1704
MEASUREMENTS MODULE
1705
GRAPHICAL USER INTERFACE
1707
SATELLITE NAVIGATION RECEIVER
1708
COMMUNICATION INTERFACE
1709
DOWN-CONVERTER
1710
ANALOG TO DIGITAL CONVERTER
1711
CORRELATOR
1712
GRAPHICAL USER INTERFACE
1713
DATA EXTRACTION MODULE
1714
TIME ANALYSIS MODULE
1715
NAVIGATION DATA PROCESSOR
1716
POSITION COMPUTATION MODULE
1716a
SATELLITE POSITION COMPUTATION MODULE
1716b
USER POSITION COMPUTATION MODULE

FIG. 17

NAVIGATION DATA CONFIGURATION FOR OPTIMAL TIME TO FIRST FIX

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a divisional application of patent application Ser. No. 14/018,443 titled "Navigation Data Configuration For Optimal Time To First Fix", filed in the United States Patent and Trademark Office on Sep. 5, 2013, which claims the benefit of the following patent applications:

1. Non-provisional patent application number 2011/CHE/2013 titled "Navigation Data Configuration For Optimal Time To First Fix", filed in the Indian Patent Office on May 6, 2013.
2. Non-provisional patent application number 4231/CHE/2011 titled "Navigation Data Structure Generation and Data Transmission For Optimal Time To First Fix", filed on 5 Dec. 2011 in the Indian Patent Office.
3. Non-provisional patent application number 4230/CHE/2011 titled "Satellite Navigation System For Optimal Time To First Fix Using Code And Carrier Diversity", filed on 5 Dec. 2011 in the Indian Patent Office.

The specifications of the above referenced patent applications are incorporated herein by reference in their entirety.

BACKGROUND

Autonomous regional satellite based navigation systems have enabled several countries to cover their territorial footprint and the footprint of their surrounding areas. A regional satellite based navigation system such as a global navigation satellite system (GNSS) caters to the needs of specific users, for example, military personnel for military applications, and civilian users for civilian applications. For example, India is planning to deploy an autonomous regional satellite navigation system, namely, the Indian regional navigational satellite system (IRNSS), for surveying, telecommunication, transportation, identifying disaster locations, public safety, etc. The purpose of this navigation system is to cater to the needs of both standard positioning service (SPS) users and also to the needs of restricted service (RES) users. The SPS and the RES modes of service are dual services supported by any GNSS catering to civilian and military requirements exclusively. A military signal is generally acquired in two modes, namely, direct and indirect. The indirect mode is typically known as SPS assisted. There is a need for generating navigation data structures that address the needs of the SPS and RES modes of service. Specifically, for the RES signal, there is a need for the navigation data structure to account for the direct mode of acquisition or the SPS assisted mode. In the SPS assisted mode, with assistance from time of week (TOW) data, the jump on to the RES signal is established. The IRNSS will deploy a satellite constellation comprising seven satellites, three of which will be in geostationary orbits and four in geosynchronous orbits. The signals will be transmitted by the satellites in two frequency bands, namely, L5 frequency band (1176.45 megahertz (MHz)) and S1 frequency band (2492.08 MHz). The SPS signal will be modulated by a 1 MHz binary phase shift keying (BPSK) signal, whereas the PS signal will use a binary offset carrier, BOC (5, 2).

A number of issues need to be addressed while designing a satellite navigation system, for example, sensitivity improvements, jamming margins, robustness towards spoofing, multipath related improvements, time to first fix (TTFF), etc., for ensuring the efficiency and robustness of the satellite navigation system. Time to first fix (TTFF) is an important parameter that needs to be optimized in most satellite navigation receivers. TTFF is a measure of the time taken by a satellite navigation receiver to acquire satellite signals and navigation data, and output a first position solution, referred to as a "fix", from power-on. The TTFF parameter directly influences the efficiency of position tracking by the satellite navigation receiver. The TTFF parameter has been examined at length and several approaches have been proposed to reduce this parameter. However, most of the approaches have concentrated on augmenting the satellite navigation receiver with data aid to the satellite navigation receiver. For an optimal TTFF performance, it is necessary that the time taken for computing navigation measurements and collecting subsequent navigation data is minimal. Typically, methods for reducing TTFF have focused on reducing the time required to acquire and lock the navigation signal, assisting the satellite navigation receiver with navigation data on a separate satellite link, etc. However, these methods are generally expensive in terms of deployment costs, complexity of the satellite navigation receiver, etc.

A typical global navigation satellite system (GNSS) signal may be characterized by the following equation:

$$s(t)=c(t)*[r(t)\oplus d(t)]$$

where the parameter s(t) refers to an output GNSS signal at a time instant t, the parameter r(t) refers to a ranging code at the time instant t, the parameter c(t) refers to a frequency of operation at the time instant t, and the parameter d(t) refers to the navigation data transmitted by each satellite.

The navigation data transmitted by each satellite can be grouped into ephemeris data and almanac data. The ephemeris data comprises precise clock and Keplerian parameters, which are typically updated once every two hours. Typically, the ephemeris data or ephemerides are transmitted periodically once every two hours. The almanac data provides a coarse estimate of a satellite orbit, which is used for satellite visibility computations. The almanac data also comprises ionosphere delay estimation coefficients for single frequency users, for example, global positioning system (GPS) L1 users. The almanac data typically changes once in a day. The satellite state vectors of a satellite computed using the ephemeris data are used for estimation of a user position and velocity.

The satellite navigation receivers of conventional satellite navigation systems have generally been constrained by the amount of time taken for collecting the ephemeris data and the almanac data that constitute the navigation data. The delay in collecting the navigation data translates to multiple delays, for example, delays in computing satellite visibility, delays in estimation of ionosphere delay estimation coefficients, delays in cross-correlation detection based on the range estimated using the almanac data and an integrity check specified by the federal aviation administration (FAA) for beta-3 civil aviation receivers, etc. Conventional satellite navigation receivers take a relatively long time, for example, about 12.5 minutes to collect the almanac data for a single frequency user. This delays the estimation of the ionosphere error, which is an important parameter for estimation of the position of the satellite.

The typical time taken by a user in open sky conditions to collect ephemeris data and almanac data from the global positioning system (GPS) and the global navigation satellite system (GLONASS) is recorded. The ephemeris data collection time in a GLONASS is, for example, about 30

seconds, and the ephemeris data collection time in a GPS is, for example, about 30 seconds. The almanac data collection time in a GLONASS is, for example, about 150 seconds, while the almanac data collection time in a GPS is, for example, about 750 seconds.

Furthermore, a conventional satellite navigation system such as the global positioning system (GPS) transmits the navigation (NAV) data, for example, as "sub-frames", while the GLONASS transmits the NAV data, for example, as "strings". In the GPS, Keplerian parameters are transmitted as a part of the navigation data while in the GLONASS, the absolute state vectors of a satellite are transmitted. Existing GPS based systems employ an L1 sub-frame structure, with the first three sub-frames comprising the ephemeris data and the last two sub-frames dedicated to the almanac data. Each sub-frame contains 10 words and each word has 24 navigation data bits and 6 parity bits. The use of 6 parity bits per word translates to 60 parity bits per sub-frame, effectively constraining the data bandwidth and delaying the time to first fix. The data bits are transmitted at 50 bits per second (bps). Therefore, one complete sub-frame is transmitted in 30 seconds. For every 24 bits, six redundant bits are transmitted. This constrains the time taken for the collection of the ephemeris data and delays the TTFF.

Furthermore, in each sub-frame, existing words and bits, for example, telemetry (TLM) data, hand over word (HOW) data, a sub-frame identifier, etc., need to be transmitted. The almanac data is transmitted in two sub-frames, for example, sub-frames 4 and 5. Moreover, the almanac data comprises ionosphere correction terms and coordinated universal time (UTC) parameters. Further, in case of current almanac transmission methods deployed in a GPS, at any given instant of time, all satellites transmit the same information as part of sub-frames 4 and 5. The sub-frames 4 and 5 transmit almanac data for all the 25 pages with each almanac page comprising the almanac data of a particular satellite. Furthermore, with the current scheme of almanac data transmission, as for example in GPS based systems, it takes about 168 seconds for a seven-satellite satellite navigation system to collect almanac data. This delays the ionosphere error computation and thus delays accurate positioning in a satellite navigation receiver. Moreover, parameters such as UTC parameters compound the delay and bandwidth overhead since the UTC parameters need not be transmitted very frequently for computation of the user's position.

A navigation (NAV) data structure of the Galileo GNSS adopts a sub-frame architecture similar to that of a GPS based system. The navigation data structure uses a 12 sub-frame structure with each sub-frame comprising a series of pages. Each page comprises a synchronization pattern and navigation data symbols. Each navigation data symbol comprises a navigation data word and tail bits. The navigation data word comprises a 24-bit cyclic redundancy check (CRC) code. Further, as in the case of other modern global navigation satellite systems (GNSSs), the Galileo adopts half rate forward error correction (FEC) encoding. For the Galileo GNSS, the integrity bits are added to a packet of navigation data. However, Galileo uses a navigation data structure with a larger number of sub-frames and imposes constraints in terms of memory requirements and an increased amount of time required for transmitting the complete navigation data structure.

The GPS L5 satellite navigation system is a global navigation satellite system that employs navigation data transmission based on the transmission of text messages at a predefined rate. Each text message is identified based on a message identifier (ID). GPS L5 uses a half rate forward error correction (FEC) encoding scheme with a baud rate of 100 symbols per second (sps). The signal transmitted from an L5 satellite is at a power level of, for example, about −157 decibel-watt (dBW). The GPS L5 satellite navigation system allows variation of frequency of text message transmission. However, the GPS L5 system continues to employ a five sub-frame structure and needs about 30 seconds for complete transmission of all the sub-frames of the navigation data structure.

Furthermore, the transmission of almanac data in a conventional global navigation satellite system (GNSS), for example, a GPS based system comprises transmission of the same almanac data by all satellites in a constellation. For example, in a seven-satellite constellation employed by the Indian regional navigational satellite system (IRNSS), each satellite transmits the same almanac data at each time instant over a satellite channel. This increases the time overhead in almanac transmission and increases the almanac data collection time at the satellite navigation receiver, thereby delaying ionosphere estimation at the satellite navigation receiver. For example, in the IRNSS, seven almanac pages need to be transmitted as a part of the third sub-frame. On using an almanac transmission scheme typically used in a GPS, it takes about 168 seconds to completely transmit the almanac data.

The number of physical channels within a receiver is not a constraint due to improvements in semiconductor technology. Several receiver manufacturers have developed receivers with an excess of 200 channels, which exist concurrently. In addition, the receivers support all in view global navigation satellite system (GNSS) satellite signal processing. The modernized signals of a global positioning system (GPS), namely, L2C and L5, and the proposed signals of Galileo and Compass navigation systems have a minimum of at least two frequencies that support civilian applications. In parallel, there exists dedicated access to their military applications. With an assumption of dual frequency, there is a need for reducing the TTFF for civilian applications, and more importantly, for the restricted users.

A study was carried out on a signaling scheme of operational navigation systems with respect to multiple frequencies of operation. Of the parameters used to compute TTFF, collection time of ephemeris data (T_{eph}) is a major contributor as T_{eph} completely depends on the navigation data structure of a particular constellation and does not depend on the satellite navigation receiver. As such, the TTFF is governed by the time required to collect ephemeris data. The objective is to reduce the T_{eph} further without increasing the satellite data rate, the power required for data transmission, etc., and thus improve TTFF. An increased data rate necessitates more signal transmission power, which is a costly proposition onboard satellites.

Hence, there is a long felt but unresolved need for a method and a system that generate a navigation data structure with a few sub-frames, for example, three sub-frames, configure the navigation data in these sub-frames to selectively accommodate navigation data, and selectively transmit the generated navigation data structure with the configured navigation data to a satellite navigation receiver in reduced time to enable faster access to the navigation data and to reduce the TTFF for civilian users and restricted users.

SUMMARY OF THE INVENTION

This summary is provided to introduce a selection of concepts in a simplified form that are further disclosed in the

detailed description of the invention. This summary is not intended to identify key or essential inventive concepts of the claimed subject matter, nor is it intended for determining the scope of the claimed subject matter.

The method and the system disclosed herein address the above mentioned needs for generating a navigation data structure with a few sub-frames, for example, three sub-frames, configuring navigation data in these sub-frames to selectively accommodate navigation data, and selectively transmitting the generated navigation data structure with the configured navigation data to a satellite navigation receiver in reduced time to enable faster access to the navigation data and to reduce time to first fix (TTFF) for civilian users and restricted users. The method and the system disclosed herein provide a signal generation system, for example, in each of multiple satellites of a constellation. The signal generation system generates a navigation signal comprising a navigation data structure. The navigation data structure is configured to selectively accommodate navigation data. The navigation data structure disclosed herein comprises a first sub-frame, a second sub-frame, and a third sub-frame. The signal generation system configures the first sub-frame and the second sub-frame to accommodate selective ephemeris data of the navigation data. The configuration of the first sub-frame and the second sub-frame reduces time for collecting the ephemeris data by the satellite navigation receiver. The signal generation system configures the third sub-frame to accommodate a text message comprising almanac data, ionospheric data, coordinated universal time (UTC) data, textual data, for example, user defined data, and any combination thereof. The configuration of the third sub-frame reduces time for collecting the almanac data, the ionospheric data, the UTC data, and the textual data by the satellite navigation receiver.

In an embodiment, the text message in the third sub-frame of the generated navigation data structure is further configured to accommodate periodic non-positioning information extracted from the first sub-frame and the second sub-frame. As used herein, the term "non-positioning information" refers to information in the navigation data structure that does not directly contribute to determination of a geographical position of a user. The periodic non-positioning information comprises, for example, telemetry data collected from the navigation data. Each of the first sub-frame, the second sub-frame, and the third sub-frame of the generated navigation data structure comprises, for example, 288 bits of the navigation data and 6 bits of tail data. In an embodiment, the signal generation system appends a synchronization word to each of the first sub-frame, the second sub-frame, and the third sub-frame. The signal generation system configures the synchronization word to enable frame synchronization and identification of a sub-frame boundary of each of the first sub-frame, the second sub-frame, and the third sub-frame.

The signal generation system selectively groups the almanac data, the ionospheric data, and the coordinated universal time (UTC) data. For example, the signal generation system groups the UTC data with the ionospheric data, or the almanac data with the ionospheric data. In an embodiment, the signal generation system verifies integrity of the navigation data in the first sub-frame, the second sub-frame, and the third sub-frame of the generated navigation data structure for determining accuracy of the navigation data. The signal generation system selectively transmits the ephemeris data, the selectively grouped almanac data, ionospheric data, and UTC data, and the textual data in the generated navigation data structure to the satellite navigation receiver. The signal generation system alternatively transmits the ionospheric data and the UTC data with the almanac data and free of the almanac data in the third sub-frame in the generated navigation data structure to transmit the navigation data in reduced time, thereby reducing the TTFF in the satellite navigation receiver. Furthermore, the method and the system disclosed herein enable each of the satellites of a constellation to simultaneously and selectively transmit the selective ephemeris data, the selectively grouped almanac data, ionospheric data, and UTC data, and the textual data in the generated navigation data structure to the satellite navigation receiver, thereby allowing the satellite navigation receiver to collectively receive the selective ephemeris data, the almanac data, the ionospheric data, the UTC data, and the textual data in reduced time, thereby further reducing the TTFF in the satellite navigation receiver.

In an embodiment for reducing TTFF in a satellite navigation receiver in a single frequency of operation, the signal generation system configures the third sub-frame of the generated navigation data structure to accommodate a text message having only the ionospheric data and the coordinated universal time (UTC) data. The configuration of the third sub-frame reduces time for collecting the ionospheric data and the UTC data by the satellite navigation receiver. In an embodiment, the signal generation system determines a mode of operation for transmitting the navigation data in the generated navigation data structure. The mode of operation is, for example, a civilian mode or a restricted mode. The signal generation system transmits the ephemeris data, the ionospheric data, and the UTC data free of the almanac data in the generated navigation data structure to the satellite navigation receiver in the determined mode of operation, thereby reducing the TTFF in the satellite navigation receiver. The ionospheric data and the UTC data are transmitted by one of multiple satellites of a constellation to the satellite navigation receiver. Furthermore, in this embodiment, the signal generation system alters transmission of the navigation data after the transmission of the ionospheric data and the UTC data to further reduce the TTFF in the satellite navigation receiver.

In the civilian mode of operation, the signal generation system staggers the navigation data in each of the sub-frames of the generated navigation data structure into a first portion and a second portion. In an embodiment, the signal generation system determines a mode of service, for example, a civilian mode of service, a restricted mode of service, etc., for transmitting the staggered navigation data in the generated navigation data structure. Each of multiple satellites of a constellation parallelly transmits each of the sub-frames of the generated navigation data structure comprising distinct staggered navigation data over a first carrier frequency, for example, the L5 frequency, and a second carrier frequency, for example, the S1 frequency in the determined mode of service to obtain the navigation data in reduced time, thereby reducing the TTFF in the satellite navigation receiver in the civilian mode of operation.

Each of the satellites is configured to transmit distinct staggered navigation data on each of the first carrier frequency and the second carrier frequency. In the civilian mode of operation, the signal generation system sequentially transmits the first portion and the second portion of each of the sub-frames over the first carrier frequency and the second carrier frequency in a first mode of service, for example, the civilian mode of service. The signal generation system sequentially transmits a complementary of the first portion and the second portion of each of the sub-frames over the second carrier frequency and the first carrier fre-

quency in a second mode of service, for example, the restricted mode of service. The signal generation system sequentially sweeps the textual data in the generated navigation data structure cyclically across the satellites on each of the first carrier frequency and the second carrier frequency in the first mode of service or the second mode of service. Furthermore, the signal generation system alternatively transmits the textual data, the ionospheric data, and the coordinated universal time (UTC) data of the navigation data in the sub-frames on the first carrier frequency or the second carrier frequency.

In the restricted mode of operation, the signal generation system staggers the navigation data in each of the sub-frames of the generated navigation data structure into a first portion and a second portion. In an embodiment, the signal generation system determines a mode of service, for example, a civilian mode of service, a restricted mode of service, etc., for transmitting the staggered navigation data in the generated navigation data structure. Each of the satellites of a constellation parallelly transmits each of the sub-frames over a first carrier frequency, for example, the L5 frequency, and a second carrier frequency, for example, the S1 frequency in the determined mode of service to obtain the navigation data in reduced time, thereby reducing the TTFF in the satellite navigation receiver in the restricted mode of operation. The signal generation system parallelly transmits each of the sub-frames by: sequentially transmitting the first portion and the second portion of each of the sub-frames over the first carrier frequency, and a complementary of the first portion and the second portion of each of the sub-frames over the second carrier frequency in a first mode of service, for example, the civilian mode of service to obtain time of week (TOW) data; sequentially transmitting the second portion of one sub-frame and the first portion of another sub-frame, and a complementary of the second portion of one sub-frame and the first portion of the other sub-frame over the first carrier frequency in a second mode of service, for example, the restricted mode of service; and sequentially transmitting the first portion of one sub-frame and the second portion of another sub-frame, and a complementary of the first portion of one sub-frame and the second portion of the other sub-frame over the second carrier frequency in the second mode of service, for example, the restricted mode of service. The first mode of service assists the second mode of service for availing the obtained TOW data in reduced time, thereby reducing the TTFF in the satellite navigation receiver.

The satellite navigation receiver disclosed herein receives navigation signals comprising the navigation data in the generated navigation data structure from multiple satellites of a constellation. The satellite navigation receiver extracts the navigation data from the received navigation signals. The satellite navigation receiver determines a sub-frame boundary of each of the first sub-frame, the second sub-frame, and the third sub-frame in the generated navigation data structure, for example, by searching for a synchronization word in the generated navigation data structure. The satellite navigation receiver decodes each of the first sub-frame, the second sub-frame, and the third sub-frame in the generated navigation data structure for extracting the navigation data. The satellite navigation receiver performs a cyclic redundancy check operation on the extracted navigation data for validating the extracted navigation data. The satellite navigation receiver extracts the selective ephemeris data, the almanac data, the ionospheric data, the coordinated universal time (UTC) data, and the textual data from the validated navigation data based on a sub-frame identifier.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing summary, as well as the following detailed description of the invention, is better understood when read in conjunction with the appended drawings. For the purpose of illustrating the invention, exemplary constructions of the invention are shown in the drawings. However, the invention is not limited to the specific methods and components disclosed herein.

FIG. **1** illustrates a method for reducing time to first fix in a satellite navigation receiver.

FIG. **2** exemplarily illustrates a navigation data structure generated by a signal generation system.

FIG. **3** exemplarily illustrates transmission of navigation data in a three sub-frame normal navigation data structure by each satellite of a seven-satellite constellation in an Indian regional navigational satellite system.

FIG. **4** exemplarily illustrates a table showing types of text messages transmitted at different time instances as part of a third sub-frame in the three sub-frame normal navigation data structure.

FIG. **5** illustrates a method for reducing time to first fix in a satellite navigation receiver in a single frequency of operation.

FIG. **6** exemplarily illustrates transmission of navigation data in a three sub-frame fixed navigation data structure by each satellite of a seven-satellite constellation in an Indian regional navigational satellite system.

FIG. **7** illustrates a method for reducing time to first fix in a satellite navigation receiver operating in a civilian mode of operation.

FIG. **8** exemplarily illustrates a timing diagram showing transmission slots of text messages for a satellite navigation receiver operating in the civilian mode of operation.

FIG. **9**A exemplarily illustrates transmission of navigation data to a satellite navigation receiver operating in the civilian mode of operation.

FIG. **9**B exemplarily illustrates staggering of navigation data within a sub-frame for reception by a satellite navigation receiver operating in the civilian mode of operation.

FIG. **10** illustrates a method for reducing time to first fix in a satellite navigation receiver operating in a restricted mode of operation.

FIG. **11**A exemplarily illustrates transmission of navigation data to a satellite navigation receiver operating in the restricted mode of operation.

FIG. **11**B exemplarily illustrates staggering of navigation data within a sub-frame for reception by a satellite navigation receiver operating in the restricted mode of operation.

FIG. **12** illustrates a graphical representation showing a comparative analysis of collection time of ephemeris data and almanac data determined using the three sub-frame normal navigation data structure based system and a global positioning system based system.

FIG. **13** illustrates a graphical representation showing a comparative analysis of collection time of ephemeris data and almanac data determined using the three sub-frame fixed navigation data structure based system and a global positioning system based system.

FIG. **14** illustrates a table showing a comparison of the three sub-frame normal navigation data structure and the three sub-frame fixed navigation data structure with a global positioning system based system.

FIG. **15** illustrates a table showing the time to first fix for a satellite navigation receiver operating in a civilian mode of operation in a single carrier frequency as well as a dual carrier frequency.

FIG. **16** illustrates a table showing the time to first fix for a satellite navigation receiver operating in a restricted mode of operation in a single carrier frequency as well as a dual carrier frequency.

FIG. **17** exemplarily illustrates a system for selectively transmitting navigation data to a satellite navigation receiver for reducing time to first fix in the satellite navigation receiver.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** illustrates a method for reducing time to first fix (TTFF) in a satellite navigation receiver, for example, a single or dual frequency Indian regional navigational satellite system (IRNSS) receiver. The method disclosed herein reduces the TTFF by reducing ephemeris time T_{eph} of the satellite navigation receiver in a single frequency mode of operation without increasing satellite data rate or power required for transmission of navigation data by the satellites. An optimal TTFF, that is, a minimal time required to transmit navigation data for "n" visible satellites with "j" sub-frames is computed using the formula below:

$$TTFF_{opt}=\min_t\Sigma_n\Sigma_j SF_{j\text{-}enc}$$

The navigation data transmitted by each satellite comprises primary navigation data and secondary navigation data. The ephemeris and clock parameters of the satellites constitute the primary navigation data whereas almanac data, coordinated universal time (UTC) data, ionospheric data such as correction terms, and message type constitutes the secondary navigation data. To achieve an optimal TTFF, the navigation data parameters need to be transmitted faster or the number of primary navigation data parameters need to be reduced. The navigation data parameters are decomposed into primary navigation data parameters and secondary navigation data parameters. The minimal time required to transmit navigation data for "n" visible satellites with "j" sub-frames is therefore computed using the formula below:

$$TTFF_{opt}=\min_t\Sigma_n\Sigma_j SF_{j\text{-}pri}+\min_t\Sigma_n\Sigma_j SF_{j\text{-}sec}$$

where $SF_{j\text{-}pri}$ and $SF_{j\text{-}sec}$ are the sub-frame symbols associated with the primary navigation data parameters and the secondary navigation data parameters respectively.

To estimate user position, the satellite navigation receiver needs to collect the ephemeris and clock parameters from satellites, which constitute the primary navigation data parameters. As such, TTFF is governed by the time required to collect the primary navigation data parameters. The method disclosed herein enhances the TTFF by increasing periodicity of the primary navigation data parameters, which is achieved by reducing the rate of transmission of secondary navigation data parameters as shown in the formula below:

$$TTFF_{opt}=\min_t\Sigma_n\Sigma_j SF_{j\text{-}pri}+\{\min_t\Sigma_n\Sigma_j SF_{j\text{-}sec}\}_{constrained}$$

The method disclosed herein provides a signal generation system, for example, in each of multiple satellites of a constellation, for generating **101** a navigation data structure configured to accommodate navigation data. The navigation data structure comprises a first sub-frame, a second sub-frame, and a third sub-frame. The signal generation system configures **101***a* the first sub-frame and the second sub-frame to accommodate selective ephemeris data of the navigation data. As used herein, the term "selective ephemeris data" refers to essential ephemeris parameters that define orbital information of a satellite. The selective ephemeris data comprises, for example, a clock data reference time of week (TOW), a reference time ephemeris parameter, clock correction parameters, Keplerian parameters, group delay differential correction terms, etc. The configuration of the first sub-frame and the second sub-frame reduces time for collecting the ephemeris data by the satellite navigation receiver.

The signal generation system configures **101***b* the third sub-frame to accommodate a text message comprising almanac data, ionospheric data, coordinated universal time (UTC) data, textual data such as user defined data, and any combination thereof. The configuration of the third sub-frame reduces time for collecting the almanac data, the ionospheric data, the UTC data, and the textual data by the satellite navigation receiver. In an embodiment, the signal generation system configures the text message in the third sub-frame of the generated navigation data structure to accommodate periodic non-positioning information extracted from the first sub-frame and the second sub-frame. As used herein, the term "non-positioning information" refers to information in the navigation data structure that does not directly contribute to determination of a geographical position of a user. The periodic non-positioning information comprises, for example, telemetry data collected from the navigation data.

The signal generation system selectively groups **102** the almanac data, the ionospheric data, and the coordinated universal time (UTC) data. For example, the signal generation system groups the UTC data with the ionospheric data, or the almanac data with the ionospheric data, or the almanac data with the UTC data in the third sub-frame. The signal generation system selectively transmits **103** the ephemeris data, the selectively grouped almanac data, ionospheric data, and UTC data, and the textual data in the generated navigation data structure to the satellite navigation receiver. The signal generation system alternatively transmits **103***a* the ionospheric data and the UTC data with the almanac data and free of the almanac data in the third sub-frame in the generated navigation data structure to transmit the navigation data in reduced time, thereby reducing the TTFF in the satellite navigation receiver. In an example, the ionospheric data and the UTC data are transmitted with the almanac data at a time instance "T_0", and the ionospheric data and the UTC data are transmitted free of the almanac data at a time instance "T_0+6". Each of the satellites of a constellation simultaneously and selectively transmits the selective ephemeris data, the selectively grouped almanac data, ionospheric data, and UTC data, and the textual data in the generated navigation data structure to the satellite navigation receiver, thereby allowing the satellite navigation receiver to collectively receive the selective ephemeris data, the almanac data, the ionospheric data, the UTC data, and the textual data in reduced time, thereby further reducing the TTFF in the satellite navigation receiver.

The satellite navigation receiver receives navigation signals comprising the navigation data in the generated navigation data structure from multiple satellites of a constellation. For example, the single frequency satellite navigation receiver receives navigation signals from seven satellites of a seven-satellite constellation associated with the Indian regional navigational satellite system (IRNSS). The satellite navigation receiver extracts the navigation data from the received navigation signals as follows: The satellite navigation receiver determines a sub-frame boundary of each of the first sub-frame, the second sub-frame, and the third sub-frame in the generated navigation data structure by searching for a synchronization word in the generated navi-

gation data structure. The synchronization word is, for example, a string of data bits with a predetermined value. The satellite navigation receiver decodes each of the first sub-frame, the second sub-frame, and the third sub-frame in the generated navigation data structure for extracting the navigation data. The satellite navigation receiver performs a cyclic redundancy check operation on the extracted navigation data for validating the extracted navigation data. The satellite navigation receiver extracts the selective ephemeris data, the almanac data, the ionospheric data, the coordinated universal time (UTC) data, and the textual data from the validated navigation data based on a sub-frame identifier.

FIG. **2** exemplarily illustrates a navigation data structure **200** generated by the signal generation system. The navigation data structure disclosed in the co-pending non-provisional patent application number 4231/CHE/2011 titled "Navigation Data Structure Generation And Data Transmission For Optimal Time To First Fix" comprises a first sub-frame **201**, a second sub-frame **202**, a third sub-frame, and a fourth sub-frame. A method for achieving the formula below is by staggering the third sub-frame and the fourth sub-frame of the navigation data structure and transmitting the third sub-frame and the fourth sub-frame alternatively as the third sub-frame **203**.

$$TTFF_{opt}=\min_t\Sigma_n\Sigma_j SF_{j\text{-}pri}+\{\min_t\Sigma_n\Sigma_j SF_{j\text{-}sec}\}_{constrained}$$

The first sub-frame **201** and the second sub-frame **202** of the navigation data structure are retained as in the four sub-frame method disclosed in the co-pending non-provisional patent application number 4231/CHE/2011. The resulting navigation data structure **200** comprising three sub-frames, that is, the first sub-frame **201**, the second sub-frame **202**, and the third sub-frame **203** as exemplarily illustrated in FIG. **2**, is herein referred to as a "three sub-frame normal (TSN) navigation data structure". The signal generation system generates the TSN navigation data structure **200** by configuring the first sub-frame **201**, the second sub-frame **202**, and the third sub-frame **203** as disclosed in the detailed description of FIG. **1**. The first sub-frame **201** and the second sub-frame **202** accommodate the ephemeris data, that is, the ephemeris parameters **209**. The third sub-frame **203** selectively accommodates the almanac data, the ionospheric data, the coordinated universal time (UTC) data, the textual data, or any combination thereof, in different message types **210** as disclosed in the detailed description of FIG. **4**. In the TSN navigation data structure **200**, the first sub-frame **201** and the second sub-frame **202** are dedicated to the ephemeris and clock parameters. The almanac data is grouped along with the textual data and transmitted alternatively in the third sub-frame **203** as exemplarily illustrated in FIG. **3**. The UTC data and the ionospheric data, for example, the ionosphere correction terms are always transmitted in the third sub-frame **203** to ensure that the UTC data and the ionospheric data are transmitted every 18 seconds.

Each of the first sub-frame **201**, the second sub-frame **202**, and the third sub-frame **203** has a sub-frame data structure **204** comprising navigation data bits **206** and tail bits **207**. Each of the first sub-frame **201**, the second sub-frame **202**, and the third sub-frame **203** of the generated navigation data structure **200** comprises 288 navigation data bits **206** and 6 tail bits **207**. The navigation data bits **206** comprise 17 bits of data on time of week (TOW) **206***a*, 2 bits of a sub-frame identifier (ID) **206***b*, 5 bits of a satellite vehicle identification (SVID) **206***c* number, 240 bits of navigation data **206***d*, and 24 bits of a cyclic redundancy check (CRC) code **206***e*. The tail bits **207** of the sub-frame data structure **204** are 6 bits long. The CRC code **206***e* verifies integrity of the navigation data in the first sub-frame **201**, the second sub-frame **202**, and the third sub-frame **203** of the generated navigation data structure **200** for determining accuracy of the navigation data as disclosed in the co-pending non-provisional patent application number 4231/CHE/2011 titled "Navigation Data Structure Generation and Data Transmission For Optimal Time To First Fix".

The signal generation system generates symbols **205** of the navigation data bits **206**, herein referred to as "navigation data symbols", for example, by applying forward error correction (FEC) encoding to each of the sub-frames **201**, **202**, and **203**. The sum of the navigation data bits **206** is 294 bits and the navigation data bits **206** are converted to navigation data symbols **205** resulting in 588 symbols. Furthermore, the signal generation system appends a synchronization word **208**, for example, a synchronization pattern of 12 bits to each of the first sub-frame **201**, the second sub-frame **202**, and the third sub-frame **203** during generation of the navigation data structure **200**. The configuration of the synchronization word **208** enables frame synchronization and identification of a sub-frame boundary of each of the first sub-frame **201**, the second sub-frame **202**, and the third sub-frame **203**. A data generation unit within the signal generation system transmits the navigation data symbols **205** of all the visible satellites to a processing unit within the signal generation system for generating a radio frequency navigation signal.

FIG. **3** exemplarily illustrates transmission of navigation data in a three sub-frame normal (TSN) navigation data structure **200** shown in FIG. **2**, by each satellite of a seven-satellite constellation in the Indian regional navigational satellite system (IRNSS). The signal generation system implemented in each of the satellites generates the TSN navigation data structure **200** and configures the navigation data in the TSN navigation data structure **200** by selectively grouping the almanac data, the ionospheric data, and the coordinated universal time (UTC) data for accommodation in the third sub-frame **203**. The signal generation system always transmits the UTC data and the ionospheric data in the third sub-frame **203** exemplarily illustrated in FIG. **2**, which ensures that the UTC data and the ionospheric data are transmitted every 18 seconds. As exemplarily illustrated in FIG. **3**, the signal generation system completes the transmission of the third sub-frame **203** every $((T_0+18)*N)$ seconds, where "N" takes values from 1 to 33600, that is, 604800 seconds in a week divided by 18 seconds. For odd values of "N", the signal generation system transmits the almanac data and for even values of "N", the signal generation system transmits textual messages, that is, any user defined data as exemplarily illustrated in FIG. **4**. In an example, the signal generation system groups and transmits the UTC data and the ionospheric data along with the almanac data for N=1, 3, 5, etc. As exemplarily illustrated in FIG. **3**, three satellite vehicles, SV1, SV2, and SV3 transmit the almanac data with the UTC data in the third sub-frame **203**, while four satellite vehicles, SV4, SV5, SV6, and SV7 transmit the almanac data with the ionospheric data in the third-sub-frame **203**. In another example, the signal generation system groups the UTC data and the ionospheric data in one text message and transmits the UTC data and the ionospheric data free of almanac data for N=2, 4, 6, etc., in one satellite. For odd and even values of "N", the signal generation system straddles pages in time to ensure that each satellite transmits the navigation data independently.

As exemplarily illustrated in FIG. **3**, at a time instance "T_0", satellites SV1, SV2, and SV3 of the seven-satellite

constellation transmit the almanac data grouped with the coordinated universal time (UTC) data, and the satellites SV4, SV5, SV6, and SV7 of the seven-satellite constellation transmit the almanac data grouped with the ionospheric data. The UTC data and the ionospheric data are transmitted every 18 seconds. For example, the satellite SV1 groups the UTC data with the ionospheric data represented as MT-3 and transmits the grouped UTC data and the ionospheric data at time instance (T_0+18) seconds as exemplarily illustrated in FIG. **3**. The textual data, for example, user defined data is represented as "MT-UD1", "MT-UD2", etc., and transmitted by satellites SV2, SV3, SV4, SV5, SV6, and SV7 at a time instance (T_0+18) seconds as exemplarily illustrated in FIG. **3**. The transmission of navigation data in this three sub-frame normal (TSN) navigation data structure **200** makes the ephemeris page available to the user from all the visible satellites within 18 seconds and therefore allows faster estimation of the user's position. The ionospheric data and the UTC data being available once every 18 seconds can be applied to correct measurements and to obtain an accurate time estimate respectively.

FIG. **4** exemplarily illustrates a table showing types of text messages transmitted at different time instances as part of a third sub-frame **203** in the three sub-frame normal (TSN) navigation data structure **200** exemplarily illustrated in FIG. **2**. The signal generation system configures the third sub-frame **203** of the generated navigation data structure **200** to selectively accommodate a text message comprising almanac data, ionospheric data, coordinated universal time (UTC) data, or any combination thereof. The primary navigation data used for TTFF and positioning are transmitted within 18 seconds as opposed to 24 seconds in a four sub-frame navigation data structure. This translates to a 40% reduction in ephemeris time T_{eph} as compared to global positioning system (GPS) or global navigation satellite system (GLONASS) L1. The signal generation system completes the transmission of the third sub-frame **203** every ((T0+18)*N) seconds, where "N" takes values from 1 to 33600, that is, 604800 seconds in a week/18 seconds. For odd values of "N", the signal generation system staggers the almanac data in all seven satellites and for even values of "N", the signal generation system staggers the text messages in one of the seven satellites. For example, the UTC data and the ionospheric data are grouped and transmitted along with the almanac data for N=1, 3, 5 . . . 33599. In another example, the UTC data and the ionospheric data are grouped and transmitted as text messages free of almanac data for N=2, 4, 6 . . . 33600.

FIG. **5** illustrates a method for reducing time to first fix (TTFF) in a satellite navigation receiver in a single frequency of operation. The signal generation system generates **101** a navigation data structure **200** comprising a first sub-frame **201**, a second sub-frame **202**, and a third sub-frame **203** configured to accommodate navigation data. The signal generation system configures **101***a* the first sub-frame **201** and the second sub-frame **202** to accommodate selective ephemeris data of the navigation data as disclosed in the detailed description of FIGS. **1-2**. The signal generation system configures **101***c* the third sub-frame **203** to accommodate a text message having ionospheric data and coordinated universal time (UTC) data. The configuration of the third sub-frame **203** reduces time for collecting the ionospheric data and the UTC data by the satellite navigation receiver. In an embodiment, the signal generation system determines **501** a mode of operation for transmitting the navigation data in the generated navigation data structure **200**. The mode of operation is, for example, a civilian mode or a restricted mode. The signal generation system transmits **502** the ephemeris data, the ionospheric data, and the UTC data free of almanac data in the generated navigation data structure **200** to the satellite navigation receiver in the determined mode of operation, thereby reducing the TTFF in the satellite navigation receiver. One of the satellites of a constellation transmits the ionospheric data and the UTC data to the satellite navigation receiver.

The theoretically achievable TTFF limit in a single frequency of operation for the Indian regional navigational satellite system (IRNSS) assumes that the UTC data and the ionospheric data are transmitted only as a part of secondary navigation data as in GPS L1. With this assumption, the signal generation system generates an optimal navigation data structure referred to as a three sub-frame fixed (TSF) navigation data structure **200** for achieving optimal TTFF. With the assumption that the almanac data is redundant for the IRNSS, the signal generation system reduces the formula below:

$$TTFF_{opt}=\min_t\Sigma_n\Sigma_j SF_{j\text{-}pri}+\{\min_t\Sigma_n\Sigma_j SF_{j\text{-}sec}\}_{constrained}$$

to

$$TTFF_{opt}=\min_t\Sigma_n\Sigma_j SF_{j\text{-}pri}+\{\min_t\Sigma_n\Sigma_j SF_{j\text{-}sec}\}_{fixed,constrained}$$

FIG. **6** exemplarily illustrates transmission of navigation data in a three sub-frame fixed (TSF) navigation data structure **200** exemplarily illustrated in FIG. **2**, by each satellite of a seven-satellite constellation in the Indian regional navigational satellite system (IRNSS). The signal generation system implemented in each of the satellites staggers the coordinated universal time (UTC) data and the ionospheric data of the navigation data satellite wise in fixed slots and transmits the UTC data and the ionospheric data free of the almanac data as part of the third sub-frame **203** in the TSF navigation data structure **200**. The first sub-frame **201** and the second sub-frame **202** transmit the ephemeris data and clock parameters of the satellites as disclosed in the detailed description of FIGS. **1-2**. The third sub-frame **203** of one of the satellites of the seven-satellite constellation then transmits the UTC data and the ionospheric data, which appear once in 18 seconds from the constellation as exemplarily illustrated in FIG. **6**. For example, at time instance "T_0" each satellite of the seven-satellite constellation transmits the first sub-frame **201**. At time instance (T_0+6) seconds, each satellite of the seven-satellite constellation transmits the second sub-frame **202**. At time instance (T_0+12) seconds, the first satellite of the seven-satellite constellation transmits the UTC data and the ionospheric data denoted as a MT-3 message in FIG. **6**, while the other satellites of the seven-satellite constellation transmit the first sub-frame **201**. The UTC data and the ionospheric data are therefore transmitted once every 18 seconds by one of the satellites of the seven-satellite constellation. For example, after the first 18 seconds, the first satellite SV1 transmits the UTC data and the ionospheric data; after the next 18 seconds, the second satellite SV2 transmits the UTC data and the ionospheric data, and so on as exemplarily illustrated in FIG. **6**.

In an embodiment, the signal generation system alters the transmission of the navigation data after the transmission of the ionospheric data and the UTC data to further reduce the TTFF in the satellite navigation receiver, that is, there is a change in the sub-frame slotting following the transmission of the UTC data and the ionospheric data. For example, satellite SV1, after (T_0+18) seconds, transmits the first sub-frame **201** instead of transmitting the second sub-frame

202 commensurate with other satellites as exemplarily illustrated in FIG. 6. This ensures that the maximum time required to collect the ephemeris data from the satellite is restricted to 18 seconds. With the primary navigation data available from six satellites, the satellite navigation receiver can estimate the position within 12 seconds. However, with the ionospheric data and the UTC data being transmitted periodically every 18 seconds, the corrections are restricted to 18 seconds. A limitation with this method is that the ephemeris data is available only from six satellites, as opposed to all seven satellites. For example, between time periods (T_0+12) seconds to (T_0+18) seconds, the ephemeris data is available for 6 seconds. Therefore, for 6 seconds, the position dilution of precision (PDOP) which is a measure of satellite geometry that indicates accuracy of measurements with respect to position, will be relatively high, which is acceptable for the IRNSS, which is a regional constellation.

FIG. 7 illustrates a method for reducing time to first fix (TTFF) in a satellite navigation receiver operating in a civilian mode of operation. The signal generation system implemented in each of the satellites of a constellation generates 101 a navigation data structure 200 comprising sub-frames 201, 202, and 203 as exemplarily illustrated in FIG. 2, configured to selectively accommodate navigation data. In this method, selective ephemeris data, ionospheric data, coordinated universal time (UTC) data, textual data, and any combination thereof constitute the navigation data as disclosed in the detailed description of FIG. 5. The configuration of the sub-frames 201, 202, and 203 reduces time for collecting the navigation data by the satellite navigation receiver. The signal generation system staggers 701 the navigation data in each of the sub-frames 201, 202, and 203 of the generated navigation data structure 200 into a first portion and a second portion as exemplarily illustrated in FIG. 9B. In an embodiment, the signal generation system determines 702 a mode of service, for example, a standard positioning service (SPS), a restricted service (RES), etc., for transmitting the staggered navigation data in the generated navigation data structure 200.

Each of the satellites of a constellation then parallelly transmits 703 each of the sub-frames 201, 202, and 203 of the generated navigation data structure 200 comprising distinct staggered navigation data over a first carrier frequency, for example, a L5 frequency, and a second carrier frequency, for example, a S1 frequency, in the determined mode of service to obtain the navigation data in reduced time, thereby reducing the TTFF in the satellite navigation receiver in the civilian mode of operation. Each of the satellites is configured to transmit distinct staggered navigation data on each of the first carrier frequency and the second carrier frequency. Each of the satellites sequentially transmits 703*a* the first portion and the second portion of each of the sub-frames 201, 202, and 203 over the first carrier frequency and the second carrier frequency in a first mode of service, for example, a standard positioning service (SPS) as disclosed in the detailed description of FIG. 9A. Each of the satellites sequentially transmits 703*b* a complementary of the first portion and the second portion of each of the sub-frames 201, 202, and 203 over the second carrier frequency and the first carrier frequency in the second mode of service, for example, a restricted service as disclosed in the detailed description of FIG. 9A. The satellites transmit the textual data, the ionospheric data, and the UTC data of the navigation data alternatively in the sub-frames 201, 202, and 203 on the first carrier frequency or the second carrier frequency. The textual data is sequentially swept cyclically across the satellites on each of the first carrier frequency and the second carrier frequency in the first mode of service or the second mode of service.

FIG. 8 exemplarily illustrates a timing diagram showing transmission slots of text messages for a satellite navigation receiver operating in the civilian mode of operation. The method disclosed herein adopts the three sub-frame fixed (TSF) navigation data structure 200 exemplarily illustrated in FIG. 2 and as disclosed in the detailed description of FIGS. 5-6 for a satellite navigation receiver operating in the civilian mode of operation. The TSF navigation data structure 200 comprises a first sub-frame 201, a second sub-frame 202, and a third sub-frame 203 as disclosed in the detailed description of FIG. 7. The first sub-frame 201 and the second sub-frame 202 accommodate selective ephemeris data, and the third sub-frame 203 of one of the satellites of the constellation accommodates coordinated universal time (UTC) data and ionospheric data, which appear once in 18 seconds from the constellation.

The signal generation system configures the third sub-frame 203 to accommodate a text message comprising the ionospheric data and the UTC data. The text message is represented as MT(n, m), where "n" is the type of text message supported as exemplarily illustrated in FIG. 4, and "m" varies from 1 to 14, that is, fourteen different types of a text message are supported, which signifies specific transmission slots in either frequency. The satellites of a seven-satellite constellation operate in a dual frequency band, that is, over a first carrier frequency and a second carrier frequency, for example, L5 frequency and S1 frequency. As exemplarily illustrated in FIG. 8, slots 1 to 7 correspond to the satellite vehicle identification (ID) numbers 1 to 7 of the satellites operating in the L5 frequency, and slots 8 to 14 correspond to satellite vehicle ID numbers 1 to 7 of the satellites operating in the S1 frequency respectively. The message slotting and sequencing of text messages exemplarily illustrated in FIG. 8 in adopted in either the standard positioning service (SPS) or the restricted service (RES). FIG. 8 exemplarily illustrates sequential sweeping of the text message cyclically across the satellites on each frequency of operation of the SPS or the RES. Specifically, a satellite transmits the text message every 18 seconds. Further, the TSF navigation data structure 200 ensures that the text message is different on each frequency of a particular satellite, which obviates dilution of precision (DOP) issues. Sequencing of text messages similar to SPS is adopted in restricted services as well. The text message slotting exemplarily illustrated in FIG. 8 is generic with respect to a particular text message transmission. For example, the UTC data and the ionospheric data can be transmitted alternatively on either the first carrier frequency or the second carrier frequency to ensure that users using a single frequency obtain ionosphere corrections faster.

FIG. 9A exemplarily illustrates transmission of navigation data to a satellite navigation receiver operating in the civilian mode of operation. The transmission of navigation data in the civilian mode of operation follows the method disclosed in the detailed description of FIGS. 7-8. The text message represented as MT(n, m) exemplarily illustrated in FIG. 8 is indicated as "SF 1" and "SF 2" in FIG. 9A, with "SF 1" and "SF 2" carrying the MT(n, m) text message corresponding to its respective slot as shown in FIG. 8. The civilian mode of operation enhances the transmission of the primary navigation data parameters and thus facilitates faster time to first fix (TTFF) in the satellite navigation receiver that supports diverse modes of operation.

The signal generation system generates symbols of the navigation data, herein referred to as "navigation data symbols" as disclosed in the detailed description of FIG. **2**. The signal generation system implemented in each satellite **901** staggers the navigation data symbols in each of the sub-frames **201**, **202**, and **203** of the three sub-frame fixed (TSF) navigation data structure **200** into a first portion **902***a* and a second portion **902***b* exemplarily illustrated in FIG. **9**B and as disclosed in the detailed description of FIG. **7**. The staggering of a sub-frame, represented as "sub-frame-N" **902** in FIG. **9**B, into a first portion **902***a* and a second portion **902***b* is accomplished as disclosed in the detailed description of FIG. **9**B. Each sub-frame **902** among the sub-frames **201**, **202**, and **203** exemplarily illustrated in FIG. **2**, comprises 600 navigation data symbols. The first three hundred navigation data symbols correspond to the first portion **902***a* of the sub-frame **902** and the next three hundred navigation data symbols correspond to the second portion **902***b* of the sub-frame **902**. The navigation data symbols are alternated in the next set. The 1200 navigation data symbols of two sub-frame effective navigation data are transmitted in 6 seconds over a first carrier frequency and a second carrier frequency for a standard positioning service (SPS) and a restricted service (RES).

The satellites **901** sequentially transmit the first portion **902***a* and the second portion **902***b* of each sub-frame **902** over the first carrier frequency, for example, L5 frequency and the second carrier frequency, for example, S1 frequency in a first mode of service, for example, SPS. A complementary of the first portion **902***a* and the second portion **902***b* of each sub-frame **902** are sequentially transmitted over the second carrier frequency and the first carrier frequency in a second mode of service, for example, RES. For example, for the SPS mode of service at time instance "T_0", the first carrier frequency, for example, L5 frequency and the second carrier frequency, for example, S1 frequency, are initialized with the first portion **902***a* of the first sub-frame **201** and the first portion **902***a* of the second sub-frame **202** respectively. At time instance "T_0+3", the first carrier frequency, for example, L5 frequency and the second carrier frequency, for example, S1 frequency, are initialized with the second portion **902***b* of the first sub-frame **201** and the second portion **902***b* of the second sub-frame **202** respectively. That is, at time instance "T_0", the L5 frequency is initialized with "SF 1-I" and the S1 frequency is initialized with "SF 2-I", and at time instance "T_0+3", the L5 frequency is initialized with "SF 1-II" and the S1 frequency is initialized with "SF 2-II" as exemplarily illustrated in FIG. **9**A.

The complementary portions **902***a* and **902***b* of the first sub-frame **201** and the second sub-frame **202** are assigned to the RES mode of service on the first carrier frequency and the second carrier frequency. For example, at time "T_0", the complementary portion of the second sub-frame **202**, that is, "SF 2-II" is assigned to L5 frequency and the complementary portion of the first sub-frame **201**, that is, "SF 1-II" is assigned to S1 frequency as exemplarily illustrated in FIG. **9**A. This method allows the portions **902***a* and **902***b* of the first sub-frame **201** and the second sub-frame **202** to be transmitted to the satellite navigation receiver from the L5 frequency and the S1 frequency for the SPS mode of service and the RES mode of service in 6 seconds. Therefore, the satellite navigation receiver can collect the navigation data in a reduced time of 6 seconds, thereby reducing the time to first fix (TTFF). For (T_0+3) seconds to (T_0+6) seconds, the above sequence is reversed across the modes of service and carrier frequencies.

On either carrier frequency of both modes of service, the satellites **901** transmit the navigation data as exemplarily illustrated in FIG. **9**A, where the carrier diversity of SPS and restricted services is met individually. This is accomplished by alternating the sub-frames on either carrier frequency. The above streaming methodology is applicable on all the seven satellites **901** independently. For the slot corresponding to the text message, commensurate navigation data, for example, any textual message is transmitted. This is applicable for only one satellite **901**. The remaining satellites **901** transmit the primary navigation data. The satellite navigation receiver operation in a single frequency of operation is unaffected by this method of navigation data transmission. In this method, in real time directly from the satellites **901**, the cold start TTFF performance of the satellite navigation receiver is equal to the hot start performance of the global positioning system (GPS) or the assisted global positioning system (AGPS) ephemeris assistance. As used herein, the term "cold start" refers to the state of the satellite navigation receiver, where the satellite navigation receiver is powered on without any prior information. Also, as used herein, the term "hot start" refers to the state of the satellite navigation receiver, where the satellite navigation receiver has access to the latest navigation data, for example, ephemeris data, either stored in a memory from the last power-on, or from an external real time aid. Furthermore, this method can be used in any emerging dual frequency global navigation satellite system (GNSS).

FIG. **9**B exemplarily illustrates staggering of navigation data within a sub-frame **902** for reception by a satellite navigation receiver operating in the civilian mode of operation. The navigation data symbols generated by the signal generation system are staggered and transmitted from the satellites **901** of the seven-satellite constellation. Each sub-frame **902** of the navigation data structure accommodates 600 navigation data symbols. For example, in the navigation data structure **200** exemplarily illustrated in FIG. **2**, the first sub-frame **201** comprises 600 symbols, the second sub-frame **202** comprises 600 navigation data symbols, and the third sub-frame **203** comprises 600 navigation data symbols. Each sub-frame **902** of the navigation data structure is staggered into two portions "N-I" **902***a* and "N-II" **902***b* as exemplarily illustrated in FIG. **9**B, where the first portion "N-I" **902***a* accommodates 300 navigation data symbols from 1 to 300 and the second portion "N-II" **902***b* accommodates 300 navigation data symbols from 301 to 600. The transmission of the staggered navigation data is exemplarily illustrated in FIG. **9**A and is disclosed in the detailed description of FIG. **9**A.

FIG. **10** illustrates a method for reducing time to first fix (TTFF) in a satellite navigation receiver operating in a restricted mode of operation. The TTFF achievable on a restricted service (RES) should be better or equal to that of a standard positioning service (SPS). The signal generation system generates **101** a navigation data structure **200** comprising sub-frames **201**, **202**, and **203** exemplarily illustrated in FIG. **2**, configured to selectively accommodate navigation data as disclosed in the detailed description of FIG. **5**. The signal generation system generates a navigation data signal from the navigation data structure **200** that assumes the navigation data on the RES is different from the navigation data on the SPS and the following assumptions are made. The acquisition of the navigation data signal is SPS assisted, that is, restricted only to obtaining time for restricted signal acquisition. The first impediment in achieving a fast TTFF for a restricted user is the time taken to collect time of week (TOW) information which takes a minimum of 6 seconds as

disclosed in the co-pending non-provisional patent application number 4230/CHE/2011 titled "Satellite Navigation System for Optimal Time to First Fix Using Code and Carrier Diversity" in the Indian regional navigational satellite system (IRNSS) signal design. In the diverse mode of satellite navigation receiver operation, the method disclosed herein reduces TOW.

In this method, selective ephemeris data, ionospheric data, coordinated universal time (UTC) data, textual data, and any combination thereof constitute the navigation data as disclosed in the detailed description of FIG. **5**. The configuration of the sub-frames **201**, **202**, and **203** in the navigation data structure **200** reduces time for collecting the navigation data by the satellite navigation receiver. The signal generation system staggers **701** the navigation data in each of the sub-frames **201**, **202**, and **203** of the generated navigation data structure **200** into a first portion and a second portion as disclosed in the detailed description of FIG. **7** and as exemplarily illustrated in FIG. **11**B. In an embodiment, the signal generation system determines **702** a mode of service, for example, a standard positioning service (SPS), a restricted service (RES), etc., for transmitting the staggered navigation data as disclosed in the detailed description of FIG. **7**. Each of the satellites of a constellation implementing the signal generation system parallelly transmits **1001** each of the sub-frames **201**, **202**, and **203** over a first carrier frequency, for example, L5 frequency, and a second carrier frequency, for example, S1 frequency, in the determined mode of service to obtain the navigation data in reduced time, thereby reducing the TTFF in the satellite navigation receiver in the restricted mode of operation.

During parallel transmission, the signal generation system sequentially transmits **1001***a* the first portion and the second portion of each of the sub-frames **201**, **202**, and **203** over the first carrier frequency, for example, L5 frequency, and a complementary of the first portion and the second portion of each of the sub-frames **201**, **202**, and **203** over the second carrier frequency, for example, S1 frequency, in a first mode of service, for example, the SPS mode of service to obtain time of week (TOW) data as exemplarily illustrated in FIG. **11**A. The signal generation system sequentially transmits **1001***b* the second portion of one sub-frame, for example, SF 2 and the first portion of another sub-frame, for example, SF 1 exemplarily illustrated in FIG. **11**A, and a complementary of the second portion of one sub-frame and the first portion of the other sub-frame over the first carrier frequency, for example, L5 frequency in a second mode of service, for example, the RES mode of service. The signal generation system sequentially transmits **1001***c* the first portion of one sub-frame, for example, SF 2 and the second portion of another sub-frame, for example, SF 1 exemplarily illustrated in FIG. **11**A, and a complementary of the first portion of one sub-frame and the second portion of the other sub-frame over the second carrier frequency, for example, S1 frequency in the second mode of service, for example, the RES mode of service. The first mode of service assists the second mode of service for availing the obtained TOW data in reduced time, thereby reducing the TTFF in the satellite navigation receiver. The difference between the civilian mode of operation and the restricted mode of operation is that the time required to collect the TOW is reduced in the restricted mode of operation, by straddling the navigation data in an opposite direction on the SPS channel, which reduces the time required to acquire the RES signal.

FIG. **11**A exemplarily illustrates transmission of navigation data to a satellite navigation receiver operating in the restricted mode of operation. The transmission of navigation data in the restricted mode of operation follows the method disclosed in the detailed description of FIG. **10**. The text message represented as MT(n, m) exemplarily illustrated in FIG. **8** is indicated as "SF 1" and "SF 2" in FIG. **11**A with "SF 1" and "SF 2" carrying the MT(n, m) text message corresponding to its respective slot as exemplarily in FIG. **8**. The signal generation system generates symbols of the navigation data, herein referred to as "navigation data symbols" as disclosed in the detailed description of FIG. **2**. The signal generation system implemented in each satellite **901** staggers the navigation data symbols in each of the sub-frames **201**, **202**, and **203** of the three sub-frame fixed (TSF) navigation data structure **200** exemplarily illustrated in FIG. **2**, into a first portion **902***a* and a second portion **902***b* exemplarily illustrated in FIG. **11**B, as disclosed in the detailed description of FIG. **7**. The staggering of a sub-frame **902**, represented as "sub-frame-N" **902** in FIG. **11**B, into a first portion **902***a* and a second portion **902***b* is accomplished as disclosed in the detailed description of FIG. **11**B. Each sub-frame **902** among the sub-frames **201**, **202**, and **203** exemplarily illustrated in FIG. **2**, comprises 600 navigation data symbols and the two sub-frame effective navigation data is 1200 symbols that are transmitted parallelly over a first carrier frequency and a second carrier frequency for the standard positioning service (SPS) and the restricted service (RES) as disclosed in the detailed description of FIG. **10**. The slotting of the sub-frames **201**, **202**, and **203** on the first carrier frequency, for example, the L5 frequency and the second carrier frequency, for example, the S1 frequency and the SPS mode of service and RES mode of service is exemplarily illustrated in FIG. **11**A.

The sub-frames on the first carrier frequency and the second carrier frequency in the SPS mode of service and the RES mode of service are identical. For example, the L5 frequency and the S1 frequency in the SPS mode of service transmit the first sub-frame **201** of the navigation data structure **200** as exemplarily illustrated in FIG. **11**A. However, the navigation data is straddled either on the first carrier frequency or the second carrier frequency of the SPS mode of service to ensure that time of week (TOW) is available within 3 seconds. This is accomplished by splitting the sub-frame **902** of S1 carrier frequency of the SPS mode of service as exemplarily illustrated in FIG. **11**B, where the navigation data is split into two portions **902***a* and **902***b* and transmitted in opposite directions on two carrier frequencies. The sub-frames **201**, **202**, and **203** are straddled on the first carrier frequency and the second carrier frequency of the RES mode of service, that is, assuming different navigation data with respect to the SPS mode of service, and thus ensure a time to first fix (TTFF) of 9 seconds including 3 seconds for collection of TOW data. If the data rate of a restricted navigation signal in a RES mode of service is increased to enable the faster transmission of primary navigation data parameters, the method disclosed herein assists the collection of TOW faster, that is, the RES mode of service is assisted by the SPS mode of service. With TOW as a pointer, a lock on the RES signal is established.

In an example of this method, for the SPS mode of service, at time instance "T_0", the first carrier frequency, for example, L5 frequency and the second carrier frequency, for example, S1 frequency, are initialized with the first portion **902***a* of the first sub-frame **201** and the second portion **902***b* of the first sub-frame **201** respectively. At time instance "T_0+3", the first carrier frequency, for example, L5 frequency and the second carrier frequency, for example, S1 frequency, are initialized with the second portion **902***b* of the first sub-frame **201** and the first portion **902***a* of the first

sub-frame **201** respectively. That is, at time instance "T_0", the L5 frequency is initialized with "SF 1-I" and the S1 frequency is initialized with "SF 1-II", and at time instance "T_0+3", the L5 frequency is initialized with "SF 1-II" and the S1 frequency is initialized with "SF 1-I" as exemplarily illustrated in FIG. **11**A. For the RES mode of service, at time instance "T_0", the first carrier frequency, for example, L5 frequency and the second carrier frequency, for example, S1 frequency, are initialized with the second portion **902***b* of the second sub-frame **202** and the first portion **902***a* of the second sub-frame **202** respectively. At time instance "T_0+3", the first carrier frequency, for example, L5 frequency and the second carrier frequency, for example, S1 frequency, are initialized with the first portion **902***a* of the first sub-frame **201** and the second portion **902***b* of the first sub-frame **201** respectively. That is, at time instance "T_0", the L5 frequency is initialized with "SF 2-II" and the S1 frequency is initialized with "SF 2-I", and at time instance "T_0+3", the L5 frequency is initialized with "SF 1-I" and the S1 frequency is initialized with "SF 1-II" as exemplarily illustrated in FIG. **11**A.

FIG. **11**B exemplarily illustrates staggering of navigation data within a sub-frame **902** for reception by a satellite navigation receiver operating in the restricted mode of operation. The navigation data symbols generated by the signal generation system are staggered and transmitted from the satellites **901** of the seven-satellite constellation. Each sub-frame **902** of the navigation data structure accommodates 600 navigation data symbols. That is, in the navigation data structure **200** exemplarily illustrated in FIG. **2**, the first sub-frame **201** comprises 600 navigation data symbols, the second sub-frame **202** comprises 600 navigation data symbols, and the third sub-frame **203** comprises 600 navigation data symbols. Each sub-frame **902** of the navigation data structure is staggered into two portions "N-I" **902***a* and "N-II" **902***b* as exemplarily illustrated in FIG. **11**B, where the first portion "N-I" **902***a* accommodates 300 navigation data symbols from 1 to 300 and the second portion "N-II" **902***b* accommodates 300 navigation data symbols from 301 to 600. The transmission of the staggered navigation data is exemplarily illustrated in FIG. **11**A and is disclosed in the detailed description of FIG. **11**A.

FIG. **12** illustrates a graphical representation showing a comparative analysis of collection time of ephemeris data and almanac data determined using the three sub-frame normal (TSN) navigation data based system and a global positioning system (GPS) based system. An altitude plot depicting the time required by the satellite navigation receiver for estimating the altitude of the user is selected to obtain an understanding of the effect of the navigation data structure **200** exemplarily illustrated in FIG. **2** on the time for collecting the navigation data by the satellite navigation receiver. The altitude plot enables testing of the relative performance in terms of the time to first fix (TTFF) using the method and system disclosed herein based on the three sub-frame normal (TSN) navigation data structure **200** when compared to a conventional GPS based system. To test the relative performance, the operation of the satellite navigation receiver is tested independently. In a first version, the three sub-frame normal (TSN) navigation data structure **200** is simulated by the signal generation system and the performance of the satellite navigation receiver is tested accordingly. In a second version, navigation data according to the five sub-frame navigation data structure **200** is generated and the satellites with the generated navigation data are tested. The TTFF from both the versions is logged for several runs and displayed using a graphical user interface. As exemplarily illustrated in FIG. **12**, there is an improvement in the TTFF performance and the time required to collect the almanac data or the text message based on the TSN navigation data structure **200** in comparison with GPS.

FIG. **13** illustrates a graphical representation showing a comparative analysis of collection time of ephemeris data and almanac data determined using the three sub-frame fixed (TSF) navigation data based system and a global positioning system (GPS) based system. An altitude plot depicting the time required by the satellite navigation receiver for estimating the altitude of the user is selected to obtain an understanding of the effect of the navigation data structure **200** exemplarily illustrated in FIG. **2** disclosed herein, on the time for collecting the ephemeris data and the almanac data by the satellite navigation receiver. The altitude plot enables testing of the relative performance in terms of the time to first fix (TTFF) using the method and system disclosed herein based on three sub-frame fixed (TSF) navigation data structure **200** when compared to the conventional GPS based system. To test the relative performance, the operation of the satellite navigation receiver is tested independently. In a first version, the three sub-frame fixed (TSF) navigation data structure **200** is simulated by the signal generation system and the performance of the satellite navigation receiver is tested accordingly. In a second version, navigation data according to the five sub-frame navigation data structure **200** is generated and the satellites with the generated navigation data are tested. The TTFF from both the versions is logged for several runs and displayed using a graphical user interface. As exemplarily illustrated in FIG. **13**, there is an improvement in the TTFF performance and the time required to collect almanac data or the text message of the TSF navigation data structure **200** in comparison with GPS.

FIG. **14** illustrates a table showing a comparison of the three sub-frame normal (TSN) navigation data structure **200** and the three sub-frame fixed (TSF) navigation data structure **200** exemplarily illustrated in FIG. **2**, with a global positioning system (GPS) based system. The testing of the relative performance of a satellite navigation receiver in terms of the time to first fix (TTFF) using the method and system disclosed herein based on the TSN navigation data structure **200** and the TSF navigation data structure **200** when compared to the conventional GPS based system is as disclosed in the detailed description of FIGS. **12-13**. The assumptions made in case of the TSF navigation data structure **200** is that the text messages are restricted to coordinated universal time (UTC) data and ionospheric data. The ephemeris time T_{eph} and the TTFF achieved using the method and system disclosed herein based on the TSN navigation data structure **200** is a 40% improvement over the ephemeris time T_{eph} and the TTFF achieved using the conventional GPS based system. The ephemeris time T_{eph} and the TTFF achieved using the method and system disclosed herein based on the TSF navigation data structure **200** is a 60% improvement over the ephemeris time T_{eph} and the TTFF achieved using the conventional GPS based system. The time required to transmit textual data or the almanac data denoted as "$T_{text\ message}/T_{alm}$" achieved using the method and system disclosed herein based on the TSN navigation data structure **200** is a 82% improvement over the time required to transmit the textual data or the almanac data achieved using the conventional GPS based system. Furthermore, global extension of the Indian regional navigational satellite system (IRNSS) with the TSN navigation data structure **200** and the TSF navigation data structure **200** is also possible.

FIG. **15** illustrates a table showing the time to first fix (TTFF) for a satellite navigation receiver operating in a civilian mode of operation in a single carrier frequency as well as a dual carrier frequency. The TTFF achieved over a single carrier frequency, for example, L5 frequency or S1 frequency, operation of the satellite navigation receiver for the standard positioning service (SPS) and a restricted service (RES) is 12 seconds. The transmission of primary navigation data parameters, that is, the ephemeris data is optimal from either the L5 frequency or S1 frequency for a SPS user, which is the TTFF of restricted users assuming the navigation data of the SPS mode of service and the RES mode of service is the same. The TTFF achieved over a dual carrier frequency, for example, L5 frequency and S1 frequency, operation of the satellite navigation receiver for the SPS mode of service and the RES mode of service is 6 seconds. The data from the L5 frequency or the S1 frequency paths effectively enables the SPS receiver to achieve an optimal TTFF. With time of week (TOW), the RES mode of service enters into a measurement mode and provides instantaneous positioning with navigation data obtained from the SPS path.

FIG. **16** illustrates a table showing the time to first fix (TTFF) for a satellite navigation receiver operating in a restricted mode of operation in a single carrier frequency as well as a dual carrier frequency. The TTFF achieved over a single carrier frequency, for example, L5 frequency or S1 frequency, operation of the satellite navigation receiver for standard positioning service (SPS) is 12 seconds. The transmission of the primary navigation data parameters, that is, the ephemeris data is identical and thus TTFF from either L5 frequency or S1 frequency remains the same. The TTFF achieved over a single carrier frequency, for example, L5 frequency or S1 frequency, operation of the satellite navigation receiver for restricted service (RES) is 18 seconds. With the navigation data being different for RES mode of service, code diversity disclosed in the co-pending non-provisional patent application number 4230/CHE/2011 titled "Satellite Navigation System for Optimal Time to First Fix Using Code and Carrier Diversity" is not applicable and thus with SPS assistance, the TTFF follows restricted users for a single carrier frequency.

The TTFF achieved over a dual-carrier frequency, for example, L5 frequency and S1 frequency, operation of the satellite navigation receiver for SPS mode of service and RES mode of service is 9 seconds. For a civilian mode of operation of the satellite navigation receiver, the navigation data from L5 frequency and S1 frequency when processed effectively results in a TTFF of 9 seconds. With TOW data available in 3 seconds as disclosed in the detailed description of FIG. **11**A, the TTFF achievable for the restricted users in the SPS assisted mode with different navigation data is 9 seconds, that is, 3 seconds to acquire the RES signal and 6 seconds to obtain the navigation data containing the ephemeris data, which is optimal from SPS assisted and different data architecture.

FIG. **17** exemplarily illustrates a system **1700** for selectively transmitting navigation data to a satellite navigation receiver **1707** for reducing time to first fix (TTFF) in the satellite navigation receiver **1707**. The system **1700** disclosed herein comprises a signal generation system **1701** that generates a navigation signal, for example, a radio frequency navigation signal that enables reduction of TTFF in the satellite navigation receiver **1707**. The signal generation system **1701** is implemented in each satellite of a constellation. The system **1700** disclosed herein further comprises a satellite navigation receiver **1707** that receives the generated radio frequency navigation signal in reduced time, extracts the navigation data from the received radio frequency navigation signal, and processes the extracted navigation data in reduced time, thereby reducing the TTFF in the satellite navigation receiver **1707**. The signal generation system **1701** and the satellite navigation receiver **1707** communicate via communication interfaces **1701***a* and **1708** respectively. The communication interfaces **1708** and **1701***a* are, for example, ports that enable coupling of the satellite navigation receiver **1707** to the signal generation system **1701**, for example, via a wired interface such as a radio frequency (RF) cable.

The signal generation system **1701** comprises a data generation unit **1702** and a processing unit **1706**. The data generation unit **1702** generates navigation data and measurements. The data generation unit **1702** of the signal generation system **1701** comprises a measurements module **1704** and a navigation data generation module **1703**. The measurements module **1704** generates characteristic measurements comprising, for example, pseudorange measurements and delta-range measurements of each satellite of a constellation. In an embodiment, the data generation unit **1702** further comprises a graphical user interface (GUI) **1705** that profiles navigation data measurements, health measurements of a satellite, etc. The navigation data generation module **1703** generates a navigation data structure **200** as exemplarily illustrated in FIG. **2**. The navigation data structure **200** comprises a first sub-frame **201** and a second sub-frame **202** configured to accommodate selective ephemeris data of the navigation data, and a third sub-frame **203** configured to accommodate a text message comprising almanac data, ionospheric data, coordinated universal time (UTC) data, textual data, and any combination thereof as disclosed in the detailed description of FIG. **1**.

The navigation data generation module **1703** comprises a sub-frame generation module **1703***a*, a data configuration module **1703***b*, a cyclic redundancy check (CRC) module **1703***c*, and an encoder **1703***d*. The sub-frame generation module **1703***a* generates sub-frames, that is, the first sub-frame **201**, the second sub-frame **202**, and the third sub-frame **203** of the navigation data structure **200** that selectively accommodate the selective ephemeris data, and the text message extrapolated from preconfigured navigation data files associated with each satellite. The preconfigured navigation data files comprise, for example, almanac files that store coarse orbital parameters and status information of the satellite, ephemeris files that store orbital and clock correction parameters for each satellite, etc. The sub-frame generation module **1703***a* further appends a synchronization word **208** to each of the first sub-frame **201**, the second sub-frame **202**, and the third sub-frame **203** as exemplarily illustrated in FIG. **2**. The synchronization word **208** is configured to enable frame synchronization and identification of a sub-frame boundary of each of the first sub-frame **201**, the second sub-frame **202**, and the third sub-frame **203**.

The data configuration module **1703***b* configures the navigation data in each of the sub-frames **201**, **202**, and **203** of the generated navigation data structure **200**. In the civilian mode of operation and the restricted mode of operation, the data configuration module **1703***b* selectively groups the almanac data, the ionospheric data, and the coordinated universal time (UTC) data. Furthermore, in the civilian mode of operation and the restricted mode of operation, the data configuration module **1703***b* staggers the navigation data in each of the sub-frames **201**, **202**, and **203** of the generated navigation data structure **200** into a first portion **902***a* and a second portion **902***b* as exemplarily illustrated in

FIG. **9**B. In the civilian mode of operation, the data configuration module **1703***b* sequentially sweeps the textual data cyclically across satellites on each of a first carrier frequency and a second carrier frequency in a first mode of service or a second mode of service. The cyclic redundancy check module **1703***c* verifies integrity of the navigation data by computing cyclic redundancy check bits for each of the first sub-frame **201**, the second sub-frame **202**, and the third sub-frame **203** of the generated navigation data structure **200** for determining accuracy of the navigation data. The encoder **1703***d* applies a forward error correcting code to the navigation data for encoding each of the first sub-frame **201**, the second sub-frame **202**, and the third sub-frame **203**, and generating symbols of the navigation data.

The processing unit **1706** of the signal generation system **1701** processes the generated navigation data structure **200** comprising the selective ephemeris data, the almanac data, the ionospheric data, the coordinated universal time (UTC) data, and the textual data, to generate, for example, a radio frequency (RF) navigation signal. The processing unit **1706** comprises a transmission module **1706***f* for transmitting the generated navigation signal to the satellite navigation receiver **1707** via the communication interface **1701***a* in reduced time, thereby reducing the TTFF in the satellite navigation receiver **1707**.

The processing unit **1706** further comprises a channel selection module **1706***a*, a digital to analog converter **1706***b*, a modulation module **1706***c*, an up-converter **1706***d*, and a mode determination module **1706***e*. The channel selection module **1706***a* selects a satellite channel that is associated with a satellite. The modulation module **1706***c* generates a carrier frequency and a ranging code, for example, a pseudorandom number (PRN) code for a satellite channel associated with a satellite, over which the generated navigation signal is to be transmitted. The ranging code is an identifier that is transmitted from the satellite to the satellite navigation receiver **1707** using which the satellite navigation receiver **1707** can determine the amount of transmission time that a navigation signal takes to reach the satellite navigation receiver **1707**. The ranging code can be used to determine the approximate distance between the satellite and the satellite navigation receiver **1707**. The modulation module **1706***c* performs an exclusive OR (EXOR) operation between the bits of the navigation data structure **200** and the ranging code received from the satellite.

The modulation module **1706***c* modulates the navigation data in the generated navigation data structure **200** received from the data generation unit **1702**, with the generated carrier frequency and the generated ranging code for generating an intermediate frequency (IF) signal. In an example, the modulation module **1706***c* modulates the EXORed navigation data onto the generated carrier frequency to generate a composite modulated IF signal. The modulation module **1706***c* uses a digital modulation technique, for example, a binary phase shift keying (BPSK) modulation technique and generates digital samples. The digital to analog converter **1706***b* converts the digital samples to an intermediate frequency (IF) signal. The up-converter **1706***d* translates the IF signal to generate the radio frequency navigation signal.

The mode determination module **1706***e* determines a mode of operation, for example, a civilian mode of operation, a restricted mode of operation, etc., for transmitting the navigation data in the generated navigation data signal. The mode determination module **1706***e* further determines a mode of service, for example, a standard positioning service (SPS), a restricted service, etc., for transmitting the staggered navigation data in the generated navigation data structure **200**.

The transmission module **1706***f* selectively transmits the configured navigation data in the generated navigation data structure **200** to the satellite navigation receiver **1707** in reduced time, thereby reducing the TTFF in the satellite navigation receiver **1707**. In an embodiment, the transmission module **1706***f* selectively transmits the ephemeris data, the selectively grouped almanac data, ionospheric data, and coordinated universal time (UTC) data, and the textual data in the generated navigation data structure **200** to the satellite navigation receiver **1707**. In another embodiment, the transmission module **1706***f* alternatively transmits the ionospheric data and the UTC data with the almanac data and free of the almanac data in the third sub-frame **203** in the generated navigation data structure **200** to transmit the navigation data in reduced time, thereby reducing the TTFF in the satellite navigation receiver **1707**. In another embodiment, the transmission module **1706***f* simultaneously and selectively transmits the selective ephemeris data, the selectively grouped almanac data, the ionospheric data, and the UTC data, and the textual data in the generated navigation data structure **200** to the satellite navigation receiver **1707**, thereby allowing the satellite navigation receiver **1707** to collectively receive the selective ephemeris data, the almanac data, the ionospheric data, the UTC data, and the textual data in reduced time, thereby further reducing the TTFF in the satellite navigation receiver **1707**.

In another embodiment, the transmission module **1706***f*, in communication with the mode determination module **1706***e*, is configured to transmit the ephemeris data, the ionospheric data, and the coordinated universal time (UTC) data free of the almanac data in the generated navigation data structure **200** to the satellite navigation receiver **1707** in the determined mode of operation, thereby reducing the TTFF in the satellite navigation receiver **1707**. The ionospheric data and the UTC data are transmitted by one of multiple satellites of a constellation to the satellite navigation receiver **1707**. In another embodiment, the transmission module **1706***f* alters transmission of the navigation data after the transmission of the ionospheric data and the UTC data to further reduce the TTFF in the satellite navigation receiver **1707**.

In the civilian mode of operation, the transmission module **1706***f* parallelly transmits each of the sub-frames **201**, **202**, and **203** comprising distinct staggered navigation data over a first carrier frequency, for example, L5 frequency, and a second carrier frequency, for example, S1 frequency, in the determined mode of service to obtain the navigation data in reduced time, thereby reducing the TTFF in the satellite navigation receiver **1707**. In the civilian mode of operation, the transmission module **1706***f* sequentially transmits the first portion **902***a* and the second portion **902***b* of each of the sub-frames **201**, **202**, and **203** over the first carrier frequency, for example, L5 frequency and the second carrier frequency, for example, S1 frequency, in a first mode of service as exemplarily illustrated in FIG. **9**A. Furthermore, in the civilian mode of operation, the transmission module **1706***f* sequentially transmits a complementary of the first portion **902***a* and the second portion **902***b* of each of the sub-frames **201**, **202**, and **203** over the second carrier frequency and the first carrier frequency in a second mode of service as exemplarily illustrated in FIG. **9**A. In an embodiment, the transmission module **1706***f* in each of multiple satellites transmits distinct staggered navigation data on each of a first carrier frequency, for example, L5

frequency, and a second carrier frequency, for example, S1 frequency. In another embodiment, the transmission module **1706***f* alternatively transmits the textual data, the ionospheric data, and the coordinated universal time (UTC) data of the navigation data in the sub-frames **201**, **202**, and **203** on a first carrier frequency, for example, L5 frequency, or a second carrier frequency, for example, S1 frequency.

In the restricted mode of operation, the transmission module **1706***f* parallelly transmits each of the sub-frames **201**, **202**, and **203** over a first carrier frequency and a second carrier frequency in a determined mode of service to obtain the navigation data in reduced time, thereby reducing the TTFF in the satellite navigation receiver **1707**. In the restricted mode of operation, the transmission module **1706***f* sequentially transmits the first portion **902***a* and the second portion **902***b* exemplarily illustrated in FIG. **11**B, of each of the sub-frames **201**, **202**, and **203** over the first carrier frequency, and a complementary of the first portion **902***a* and the second portion **902***b* of the each of the sub-frames **201**, **202**, and **203** over the second carrier frequency in a first mode of service to obtain time of week (TOW) data as exemplarily illustrated in FIG. **11**A. In the restricted mode of operation, the transmission module **1706***f* sequentially transmits the second portion **902***b* of one sub-frame and the first portion **902***a* of another sub-frame, and a complementary of the second portion **902***b* of one sub-frame and the first portion **902***a* of the other sub-frame over the first carrier frequency in a second mode of service as exemplarily illustrated in FIG. **11**A. Furthermore, in the restricted mode of operation, the transmission module **1706***f* sequentially transmits the first portion **902***a* of one sub-frame and the second portion **902***b* of another sub-frame, and a complementary of the first portion **902***a* of one sub-frame and the second portion **902***b* of the other sub-frame over the second carrier frequency in the second mode of service as exemplarily illustrated in FIG. **11**A. The first mode of service assists the second mode of service for availing the obtained TOW data in reduced time, thereby reducing the TTFF in the satellite navigation receiver **1707**.

The processing unit **1706** of the signal generation system **1701** transmits the radio frequency navigation signal generated by the signal generation system **1701** to the satellite navigation receiver **1707** via the communication interface **1701***a*, for example, using a radio frequency (RF) cable, thereby allowing the satellite navigation receiver **1707** to process the radio frequency navigation signal in reduced time. This reduces the TTFF in the satellite navigation receiver **1707**. The satellite navigation receiver **1707** comprises the communication interface **1708**, a radio frequency down-converter **1709**, an analog to digital converter (ADC) **1710**, a correlator **1711**, a data extraction module **1713**, a time analysis module **1714**, a navigation data processor **1715**, and a position computation module **1716**. The communication interface **1708** of the satellite navigation receiver **1707** receives the radio frequency navigation signal generated by the signal generation system **1701**. The radio frequency down-converter **1709** converts the received radio frequency navigation signal to an intermediate frequency (IF) signal. The analog to digital converter **1710** converts the intermediate frequency signal to digital samples. The correlator **1711** correlates the digital samples of the navigation signal with locally generated signals, for example, reference digital samples. This enables data bit demodulation and further decoding of the navigation data structure **200**.

The data extraction module **1713** defines instructions for extracting navigation data from the generated navigation data structure **200** contained in the navigation signal in reduced time. The data extraction module **1713** defines instructions for decoding the correlated digital samples received from the correlator **1711** to extract the navigation data from the navigation data structure **200**. The position computation module **1716** defines instructions for processing the extracted navigation data for computing, for example, a geometric position of each satellite and estimating a geographical position of a user based on the processed navigation data in reduced time. The position computation module **1716** comprises a satellite position computation module **1716***a* and a user position computation module **1716***b*. The satellite position computation module **1716***a* defines instructions for processing the extracted navigation data for computing the position of the satellite based on the processed navigation data. The satellite position computation module **1716***a* further defines instructions for computing the geometric range and range-rate of each satellite. The user position computation module **1716***b* defines instructions for estimating a geographical position of a user, that is, latitude, longitude, altitude, etc., of the user, for example, by applying a standard global positioning system (GPS) based triangulation algorithm.

The time analysis module **1714** defines instructions for analyzing timing components that constitute the TTFF, and identifying timing delays at the satellite navigation receiver **1707**. The timing components comprise a time for boot-up of the satellite navigation receiver **1707**, a time for acquiring coarse estimates of a code phase and a carrier Doppler frequency of visible satellites of a constellation over satellite channels corresponding to the visible satellites, a time for performing bit synchronization of the satellite channels corresponding to the visible satellites, a time for extracting the navigation data from the generated navigation data structure **200** contained in the navigation signals received from the visible satellites by the satellite navigation receiver **1707**, and a time for computing a geographical position of a user based on the extracted navigation data.

The navigation data processor **1715** retrieves the instructions defined by the data extraction module **1713**, the time analysis module **1714**, and the position computation module **1716** comprising the satellite position computation module **1716***a* and the user position computation module **1716***b*, and executes the instructions, thereby performing one or more processes defined by those instructions. Furthermore, the navigation data processor **1715** processes the extracted navigation data for computing the position of each satellite. The navigation data processor **1715** determines a geographical position of a user based on the processed navigation data in reduced time.

In an embodiment, the satellite navigation receiver **1707** further comprises a graphical user interface (GUI) **1712** for profiling navigation data measurements, the status of reception of the navigation data, health parameters of a satellite being tracked, etc. The GUI **1712**, for example, displays individual satellite identifiers, acquisition and tracking status with reference to the collection of the navigation data, the constellation number, position coordinates of the satellite with reference to the earth-centered, earth-fixed (ECEF) coordinate system, a geographical position of a user, that is, the latitude, longitude, and altitude of the user, the time to first fix (TTFF), the geographical position of the user such as the latitude, longitude, and altitude of the user, etc.

The foregoing examples have been provided merely for the purpose of explanation and are in no way to be construed as limiting of the present invention disclosed herein. While the invention has been described with reference to various embodiments, it is understood that the words, which have

been used herein, are words of description and illustration, rather than words of limitation. Further, although the invention has been described herein with reference to particular means, materials, and embodiments, the invention is not intended to be limited to the particulars disclosed herein; rather, the invention extends to all functionally equivalent structures, methods and uses, such as are within the scope of the appended claims. Those skilled in the art, having the benefit of the teachings of this specification, may affect numerous modifications thereto and changes may be made without departing from the scope and spirit of the invention in its aspects.

We claim:

1. A method for reducing time to first fix in a satellite navigation receiver, comprising:

generating a navigation data structure, by a navigation data generation module of a signal generation system, said generation of said navigation data structure comprising:

generating sub-frames of said navigation data structure, by a sub-frame generation module of said signal generation system, said sub-frames accommodating navigation data, said navigation data comprising ephemeris data, ionospheric data, coordinated universal time data, user defined data, and any combination thereof;

staggering said navigation data in each of said sub-frames of said generated navigation data structure into a first portion and a second portion;

processing said generated navigation data structure to generate a navigation signal, by a processing unit of said signal generation system; and

transmitting said generated navigation signal to said satellite navigation receiver, by a transmission module of said processing unit of said signal generation system, wherein said transmission of said generated navigational signal comprises:

parallelly transmitting said each of said sub-frames of said generated navigation data structure to said satellite navigation receiver over a first carrier frequency and a second carrier frequency by each of a plurality of satellites of a constellation to obtain said navigation data in reduced time, thereby reducing said time to first fix in said satellite navigation receiver.

2. The method of claim **1**, wherein said parallel transmission of said each of said sub-frames of said generated navigation data structure to said satellite navigation receiver comprises:

sequentially transmitting said first portion and said second portion of said each of said sub-frames to said satellite navigation receiver over said first carrier frequency and said second carrier frequency in a first mode of service; and

sequentially transmitting a complementary of said first portion and said second portion of said each of said sub-frames to said satellite navigation receiver over said second carrier frequency and said first carrier frequency in a second mode of service.

3. The method of claim **1**, wherein said parallel transmission of said each of said sub-frames of said generated navigation data structure to said satellite navigation receiver comprises:

sequentially transmitting said first portion and said second portion of said each of said sub-frames over said first carrier frequency, and a complementary of said first portion and said second portion of said each of said sub-frames to said satellite navigation receiver over said second carrier frequency in a first mode of service to obtain time of week data;

sequentially transmitting said second portion of one of said sub-frames and said first portion of another one of said sub-frames, and a complementary of said second portion of said one of said sub-frames and said first portion of said another one of said sub-frames to said satellite navigation receiver over said first carrier frequency in a second mode of service; and

sequentially transmitting said first portion of said one of said sub-frames and said second portion of said another one of said sub-frames, and a complementary of said first portion of said one of said sub-frames and said second portion of said another one of said sub-frames to said satellite navigation receiver over said second carrier frequency in said second mode of service, wherein said second mode of service is assisted by said first mode of service for availing said obtained time of week data in reduced time, thereby reducing said time to first fix in said satellite navigation receiver.

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