Reconfigurable & embedded Digital Systems

heig-vd
Haute Ecole d'Ingénierie et de Gestion du Canton de Vaud

GPS
Introduction

Cours APS
Aditya Kumar
Version 1.0 (2012-2013)

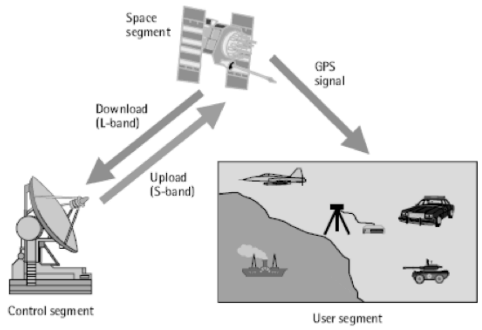
Overview

- Developed by U.S Department of Defense in early 1970's.
- Initially developed for military needs. Now it is available for civilian use.
- Provides continuous position and timing information any where in the world under any weather condition.
- Serves unlimited number of users.
- One way information exchange between receiver and GPS satellites.

Contd…

GPS consists of 3 segment:

- Space segment
- Control segment
- User segment



In a fix!

- To make a fix, a receiver must:
  - Find satellite signals and lock onto them
  - Get the ephemeris for each satellite
  - Measure the Pseudorange to each satellite
  - Determine the precise time
  - Solve the navigation equation

- Time to provide the first navigation solution is called Time To First Fix (TTFF)
  - Usually, the weaker the signal, the longer the TTFF
  - TTFF can be shortened with saved information or with aiding

Signal

- The satellites transmit signal on 2 frequency called the carrier frequency., modulated by 2 digital codes and the navigation data.
- The carrier frequency are L1 (1575 MHz) and L2 (1227 MHz).
- All satellites transmit using these 2 frequency. However they have different codes.
- The 2 GPS codes are called the coarse acquisition (C/A - code) and precision (P-code).
- These codes are called pseudo random codes (PRN).
- Presently C/A- code is modulated onto the L1 frequency only. P-code is modulated onto both the frequency.
- Bi-phase modulation.

5 Cours APS - Institut REDS/HEIG-VD – GPS

The center frequency of L1 is at 1575.42 MHz and L2 is at 1227.6 MHz. These frequencies are coherent with a 10.23 MHz clock. These two frequencies can be related to the clock frequency as

L1 = 1575.42 MHz = 154 × 10.23 MHz

L2 = 1227.6 MHz = 120 × 10.23 MHz

C/A Code

========

It is a stream of 1023 bits which repeats itself every millisecond.

The chip rate hence is 1.023Mbps.

Each satellite is assigned a unique code which enables the receiver to identify which satellite signal it is receiving.

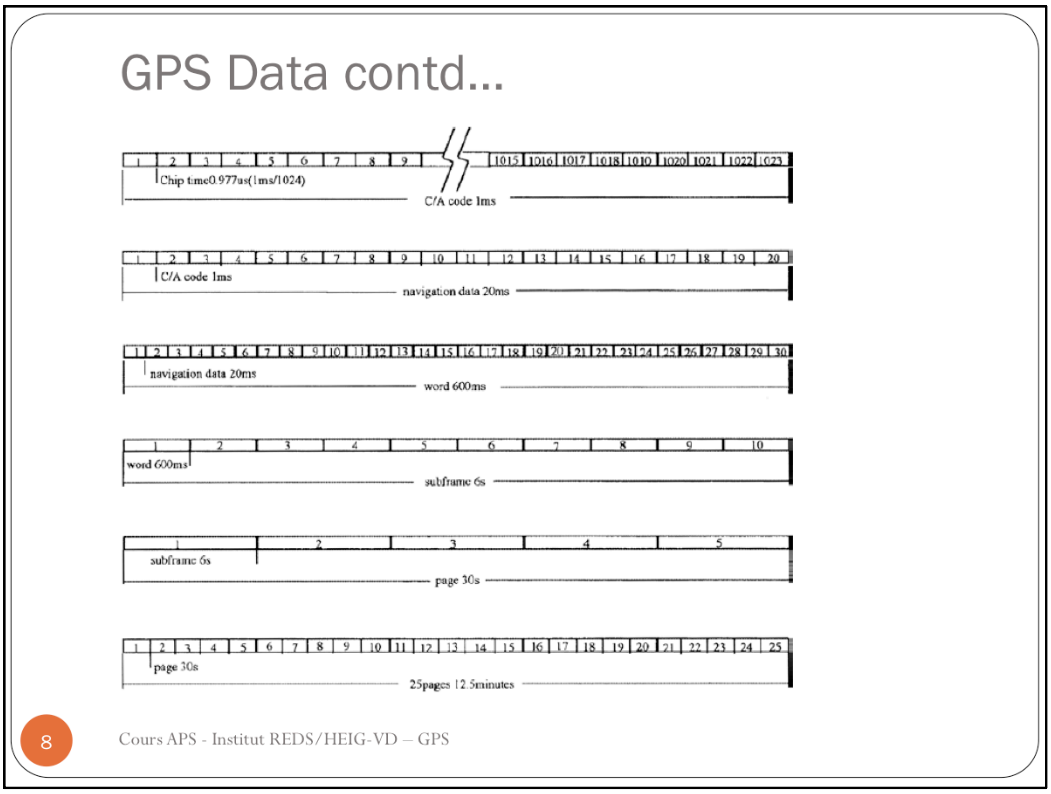
The measurement done using this code are less precise in comparison with the P-code signals.

Contd…

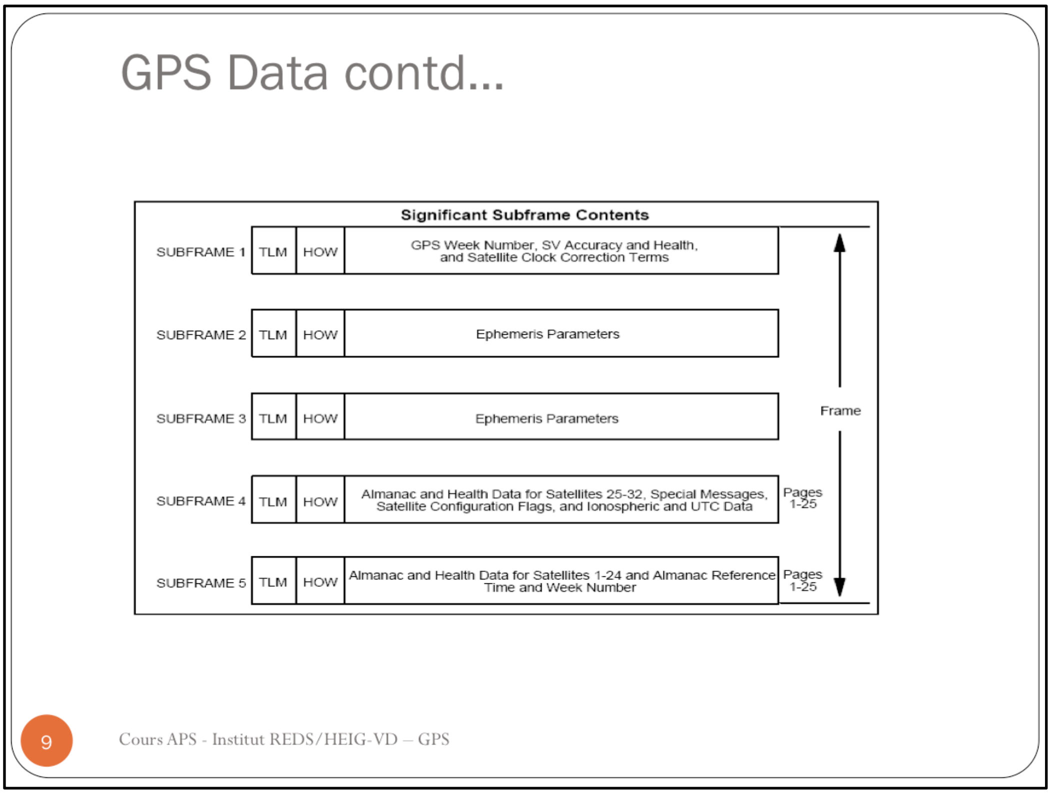
- The GPS navigation message data rate is 50bps.
- It consists of 25 frames of 1500bits each.
- Hence it takes 750 seconds for the transmission of complete GPS message.
- The message contains information about the co-ordinates of the satellite as a function of time, health of satellite, satellite clock correction, satellite almanac and atmospheric data.
- Since the C/A code is 1 ms, there are 20 C/A codes in one data bit.
- In one data bit all 20 C/A codes have the same phase. If there is a phase transition due to the data bit, the phases of the two adjacent C/A codes are different by $\pm\pi$.

GPS Data

- The satellites broadcast two types of data, Almanac and Ephemeris.
- Almanac data is course orbital parameters for all SVs. Each SV broadcasts Almanac data for ALL SVs. This Almanac data is not very precise and is considered valid for up to several months.
- Ephemeris data is very precise orbital and clock correction for each SV and is necessary for precise positioning. EACH SV broadcasts ONLY its own Ephemeris data. This data is only considered valid for about 30 minutes. The Ephemeris data is broadcast by each SV every 30 seconds.



30 data bits make up a word – word duration 600ms
10 word make a subframe - subframe duration 6s – 300bits
5 subframe make a frame – frame duration 30 s – 1500 bits
25 frame make a super frame – super frame duration 750 s – 37500bits



ach sub-frame and/or page of a sub-frame starts with a Telemetry (TLM) word and a Handover word (HOW) pair. The TLM word is transmitted first, immediately followed by the HOW. The latter is followed by eight data words. Each word in each frame contains parity.

The TLM word begins with an 8-bit preamble, followed by 16 reserved bits and 6 parity bits. The bit pattern of the preamble is shown in this figure. The bit pattern of the preamble will be used to match the navigation data to detect the beginning of a sub frame.

HOW
=====

The first 17 bits (1–17) are the truncated time of week (TOW) count that provides the time of the week in units of 6 seconds. The TOW is the truncated LSB of the Z count.

The next two bits (18, 19) are flag bits. For satellite configuration 001 (block II satellite) bit 18 is an alert bit and bit 19 is anti spoof. Satellites are procured in blocks. Most block I satellites are experimental ones and all the satellites in orbit are from block II. When bit 18 = 1, it indicates that the satellite user range accuracy may be worse than indicated in sub frame 1 and the user uses the satellite at the user’s own risk. Bit 19 = 1 indicates the anti spoof mode is on.

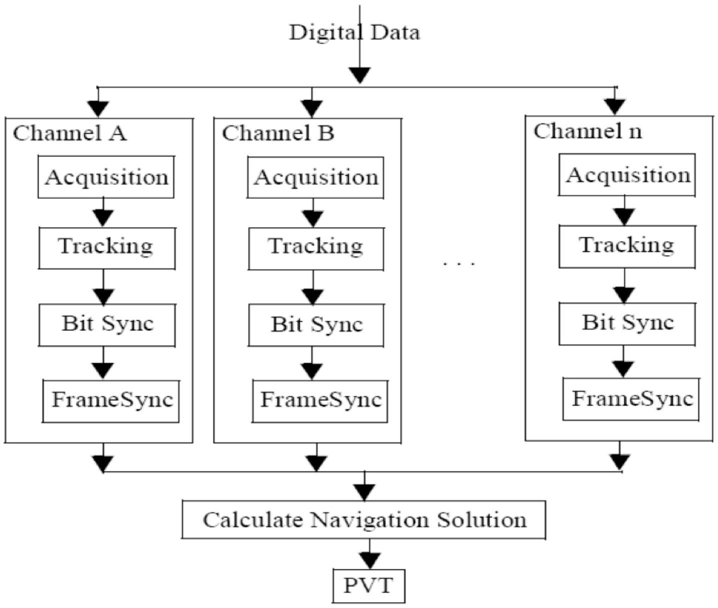
The following three bits (20–22) are the sub frame ID and their values are 1, 2, 3, 4, and 5 or (001, 010, 011, 100, and 101) to identify one of the five sub frames. These data will be used for sub frame matching.

The last 8 bits (23–30) are used for parity bits.

(Backup)

- The GPS time is given by the number of seconds in one week and this value is reset every week at the end/start of a week.
- At end/start of a week the cyclic paging to sub frames 1 through 5 will restart with sub frame 1 regardless of which sub frame was last transmitted prior to end/start of week.
- The cycling of the 25 pages will restart with page 1 of each of the sub frames, regardless of which page was the last to be transmitted prior to the end/start of week.
- All upload and page cutovers will occur on frame boundaries (i.e., modulo 30 seconds relative to end/start of week). Accordingly, new data in sub frames 4 and 5 may start to be transmitted with any of the 25 pages of these sub frames.

GPS Rx-er


Digital Data
Channel A
Acquisition
Tracking
Bit Sync
FrameSync
Channel B
Acquisition
Tracking
Bit Sync
FrameSync
. . .
Channel n
Acquisition
Tracking
Bit Sync
FrameSync
Calculate Navigation Solution
PVT

Acquisition & Tracking

- **Acquisition** is a coarse synchronization process giving estimates of the PRN code offset and the carrier Doppler.
- This information is then used to initialize the tracking loops.

- **Tracking** - Done in order to track the variations in the carrier Doppler and code offset due to line of sight dynamics between the satellite and the receiver.

Bit Sync & Frame Sync
=================

The beginning of each C/A-code period is known after C/A-code acquisition, but it is not known where the NAV-bit data, which is composed of C/A-code periods, begins.
The bit synchronization task is to find the bit boundaries.
Find the beginning of frame.

What does GPS tell us

- Time ! Nothing but Time
- Triangulation

C/A (Coarse/Acquisition)

P(Y) : Precision – Military use – encrypted

Frequencies:

L1 : 1.57542 GHz : C/A, P(Y)
L2 : 1.2276 Ghz P(Y)

L3: NUDET (Nuclear Detonation Detection)
L4: Ionospheric correction
L5: (Proposed) Civilian Safety-of-Life signal

Signals

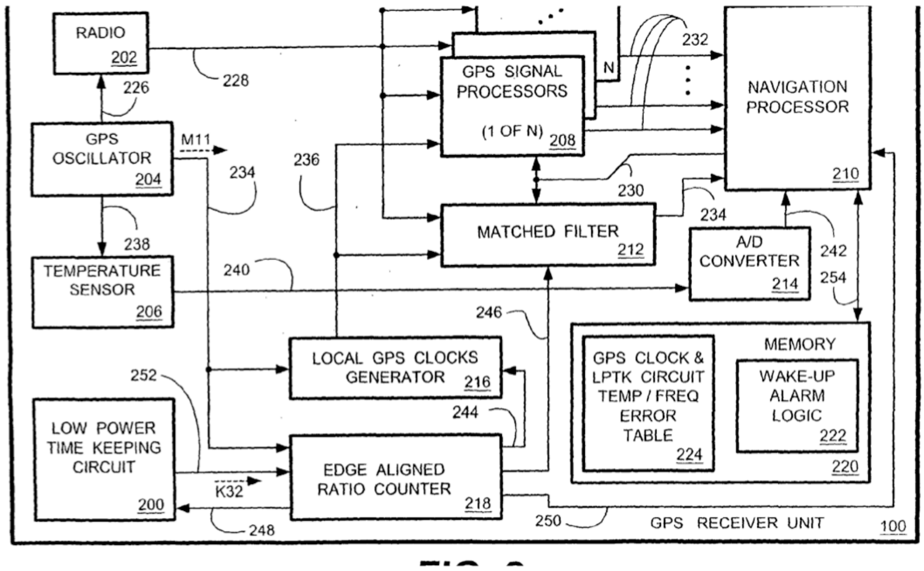
C/A (Coarse/Acquisition)

P(Y) : Precision – Military use – encrypted

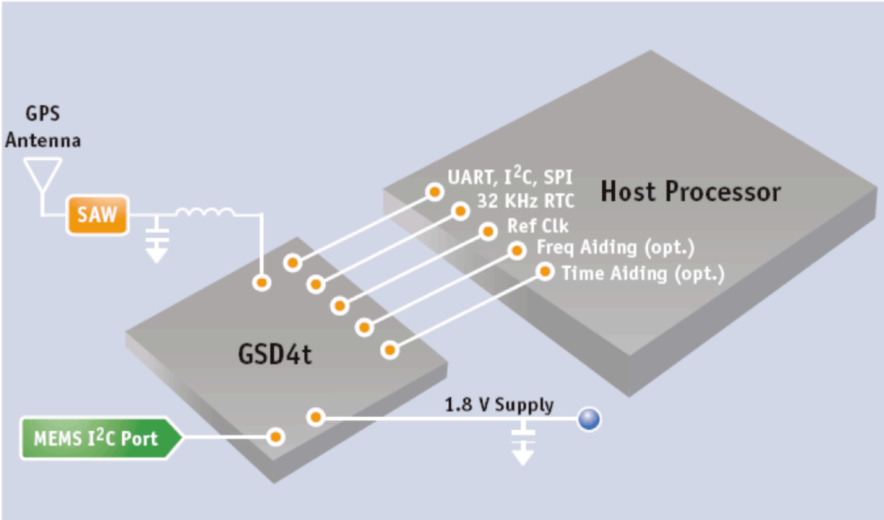
Frequencies:

L1 : 1.57542 GHz : C/A, P(Y)
L2 : 1.2276 Ghz P(Y)

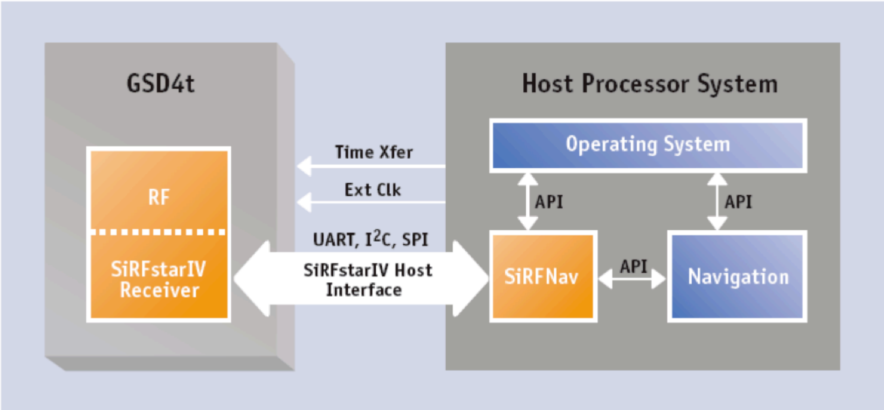
L3: NUDET (Nuclear Detonation Detection)
L4: Ionospheric correction
L5: (Proposed) Civilian Safety-of-Life signal


RADIO
202
226
228
GPS OSCILLATOR
204
M11
234
236
GPS SIGNAL PROCESSORS
(1 OF N)
208
N
232
NAVIGATION PROCESSOR
210
230
238
TEMPERATURE SENSOR
206
240
MATCHED FILTER
212
234
A/D CONVERTER
214
242
254
246
LOCAL GPS CLOCKS GENERATOR
216
252
MEMORY
GPS CLOCK & LPTK CIRCUIT TEMP / FREQ ERROR TABLE
224
WAKE-UP ALARM LOGIC
222
220
244
LOW POWER TIME KEEPING CIRCUIT
200
K32
EDGE ALIGNED RATIO COUNTER
218
248
250
GPS RECEIVER UNIT
100

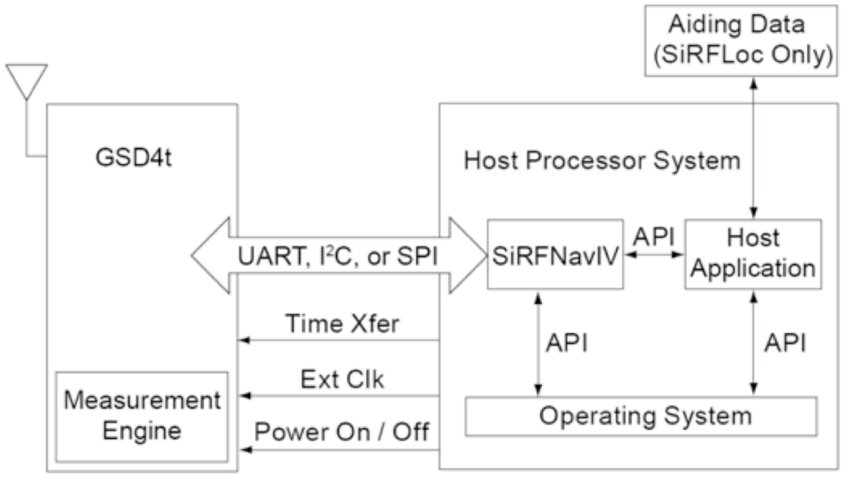
SiRF Star IV (Tracker)



Tracker Architecture

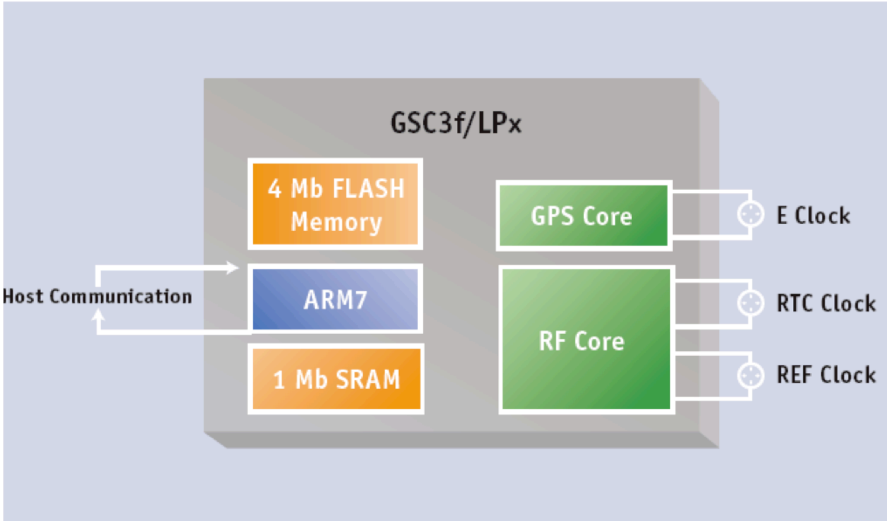


Contd...

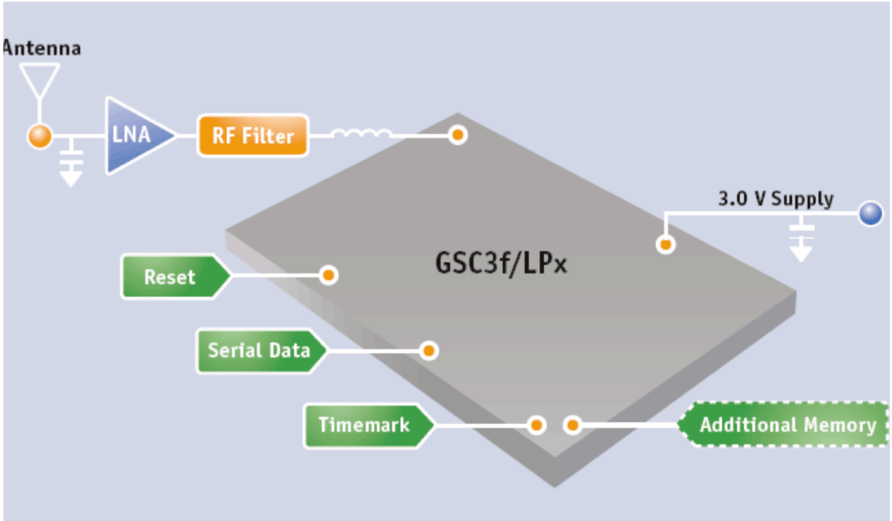


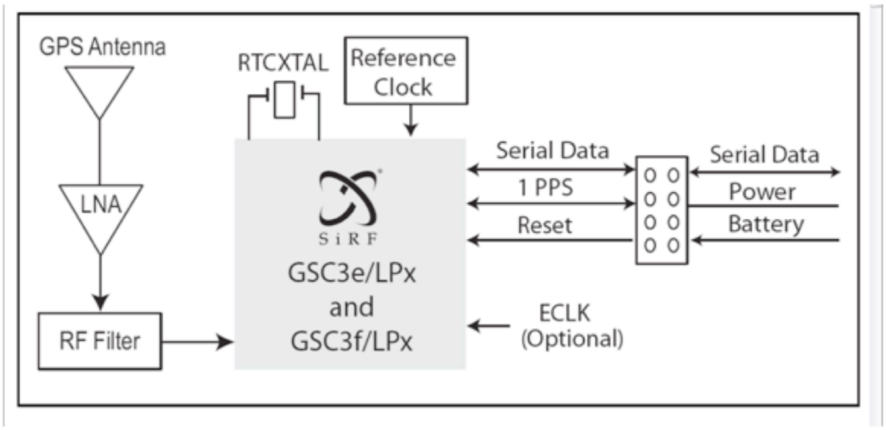
Aiding Data
(SiRFLoc Only)
GSD4t
Host Processor System
UART, I²C, or SPI
SiRFNavIV
API
Host
Application
Time Xfer
API
API
Ext Clk
Measurement
Engine
Operating System
Power On / Off

Standalone


GSC3f/LPx
4 Mb FLASH Memory
ARM7
1 Mb SRAM
GPS Core
RF Core
Host Communication
E Clock
RTC Clock
REF Clock

Contd…


Antenna
LNA
RF Filter
3.0 V Supply
GSC3f/LPx
Reset
Serial Data
Timemark
Additional Memory


GPS Antenna
RTCXTAL
Reference Clock
LNA
SiRF
GSC3e/LPx and GSC3f/LPx
Serial Data
1 PPS
Reset
Serial Data
Power
Battery
RF Filter
ECLK (Optional)

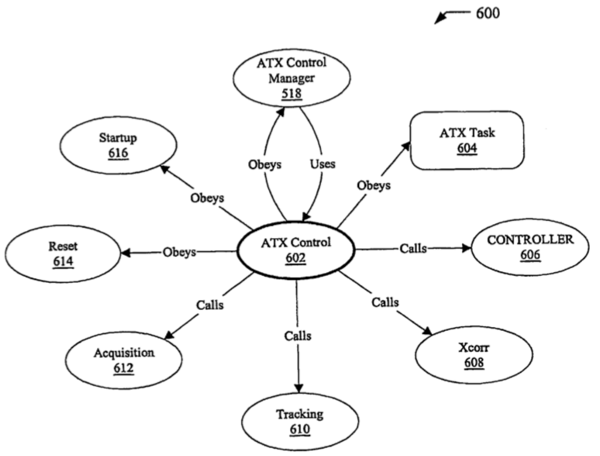

600
ATX Control Manager 518
Startup 616
ATX Task 604
Obeys
Uses
Obeys
Obeys
Reset 614
Obeys
ATX Control 602
Calls
CONTROLLER 606
Calls
Calls
Calls
Acquisition 612
Xcorr 608
Tracking 610

FIG. 6

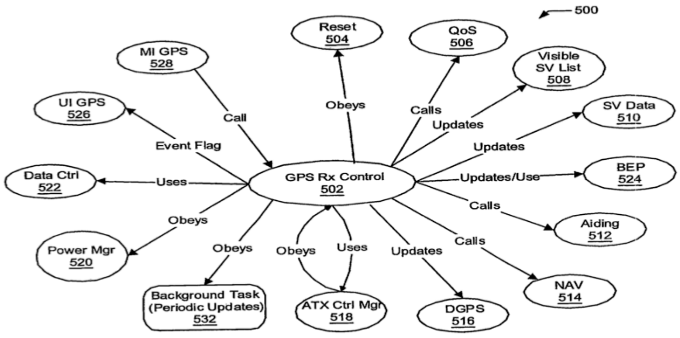

500
Reset
504
QoS
506
Visible
SV List
508
MI GPS
528
UI GPS
526
SV Data
510
Call
Obeys
Calls
Updates
Event Flag
Updates
Data Ctrl
522
Uses
GPS Rx Control
502
Updates/Use
BEP
524
Calls
Aiding
512
Obeys
Power Mgr
520
Obeys
Obeys
Uses
Updates
Calls
NAV
514
Background Task
(Periodic Updates)
532
ATX Ctrl Mgr
518
DGPS
516

FIG. 5

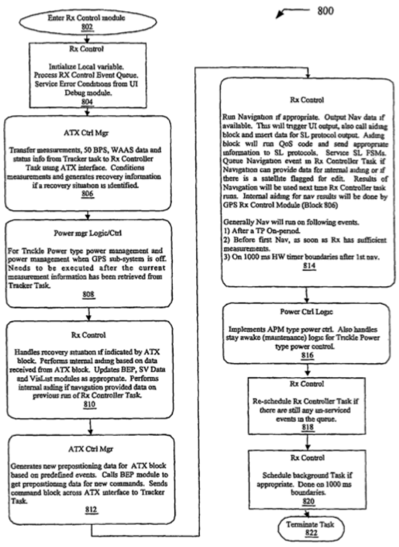

800
Enter Rx Control module
802
Rx Control
Initialize Local variable.
Process RX Control Event Queue.
Service Error Conditions from UI Debug module.
804
ATX Ctrl Mgr
Transfer measurements, 50 BPS, WAAS data and status info from Tracker task to Rx Controller Task using ATX interface. Conditions measurements and generates recovery information if a recovery situation is identified.
806
Power mgr Logic/Ctrl
For Trickle Power type power management and power management when GPS sub-system is off. Needs to be executed after the current measurement information has been retrieved from Tracker Task.
808
Rx Control
Handles recovery situation if indicated by ATX block. Performs internal aiding based on data received from ATX block. Updates BEP, SV Data and VisList modules as appropriate. Performs internal aiding if navigation provided data on previous run of Rx Controller Task.
810
ATX Ctrl Mgr
Generates new prepositioning data for ATX block based on predefined events. Calls BEP module to get prepositioning data for new commands. Sends command block across ATX interface to Tracker Task.
812
Rx Control
Run Navigation if appropriate. Output Nav data if available. This will trigger UI output, also call aiding block and insert data for SL protocol output. Aiding block will run QoS code and send appropriate information to SL protocols. Service SL FSMs. Queue Navigation event in Rx Controller Task if Navigation can provide data for internal aiding or if there is a satellite flagged for edit. Results of Navigation will be used next time Rx Controller task runs. Internal aiding for nav results will be done by GPS Rx Control Module (Block 806)
Generally Nav will run on following events.
1) After a TP On-period.
2) Before first Nav, as soon as Rx has sufficient measurements.
3) On 1000 ms HW timer boundaries after 1st nav.
814
Power Ctrl Logic
Implements APM type power ctrl. Also handles stay awake (maintenance) logic for Trickle Power type power control.
816
Rx Control
Re-schedule Rx Controller Task if there are still any un-serviced events in the queue.
818
Rx Control
Schedule background Task if appropriate. Done on 1000 ms boundaries.
820
Terminate Task
822

FIG. 8

Références

- **Control and features for satellite positioning system receivers, Patent US 8013787 B2.**