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(52) UK CL (Edition N)
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(56) Documents Cited
GB 2264837 A **EP 0574009 A2** **US 4751512 A**

(58) Field of Search
UK CL (Edition M) **H4D DPBC**
INT CL[5] **G01S 5/14**
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(54) Differential global positioning system

(57) A mobile station receives information from a reference station by way of the HF communications receiver 11, 12, 13. The information transmitted by the reference station includes range and range rate estimates calculated from uncorrected PPS radio navigation signals without consideration of the true position of the reference station. The mobile station has a conventional GPS antenna 14 which feeds data to a processor module 17, which also receives range and time of measurement information from the reference station via the interface module 18. The processor module is further provided with PPS data and the SA correction function via the interface module 19, and with information as to the true position of the reference station.

Thus the mobile station can effect uncorrected range and range rate measurements in the usual way and can then effect differential error correction at the mobile station without the reference station requiring access to decryption information.

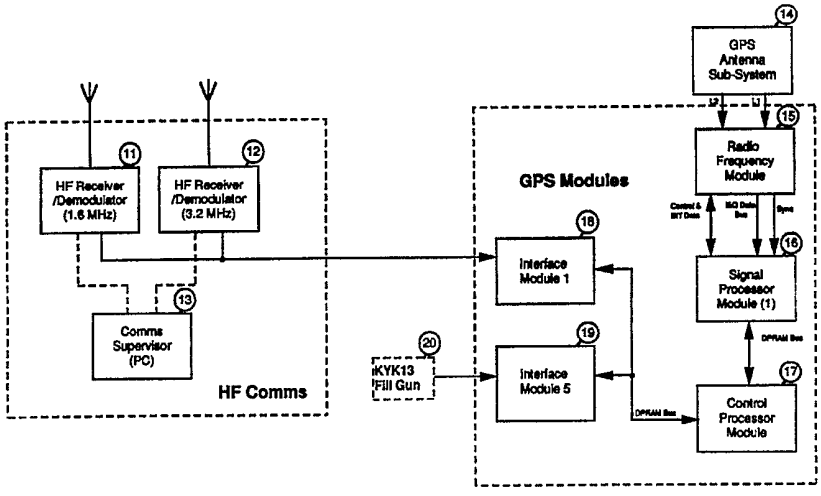

Figure 1.

GB 2 287 149 A

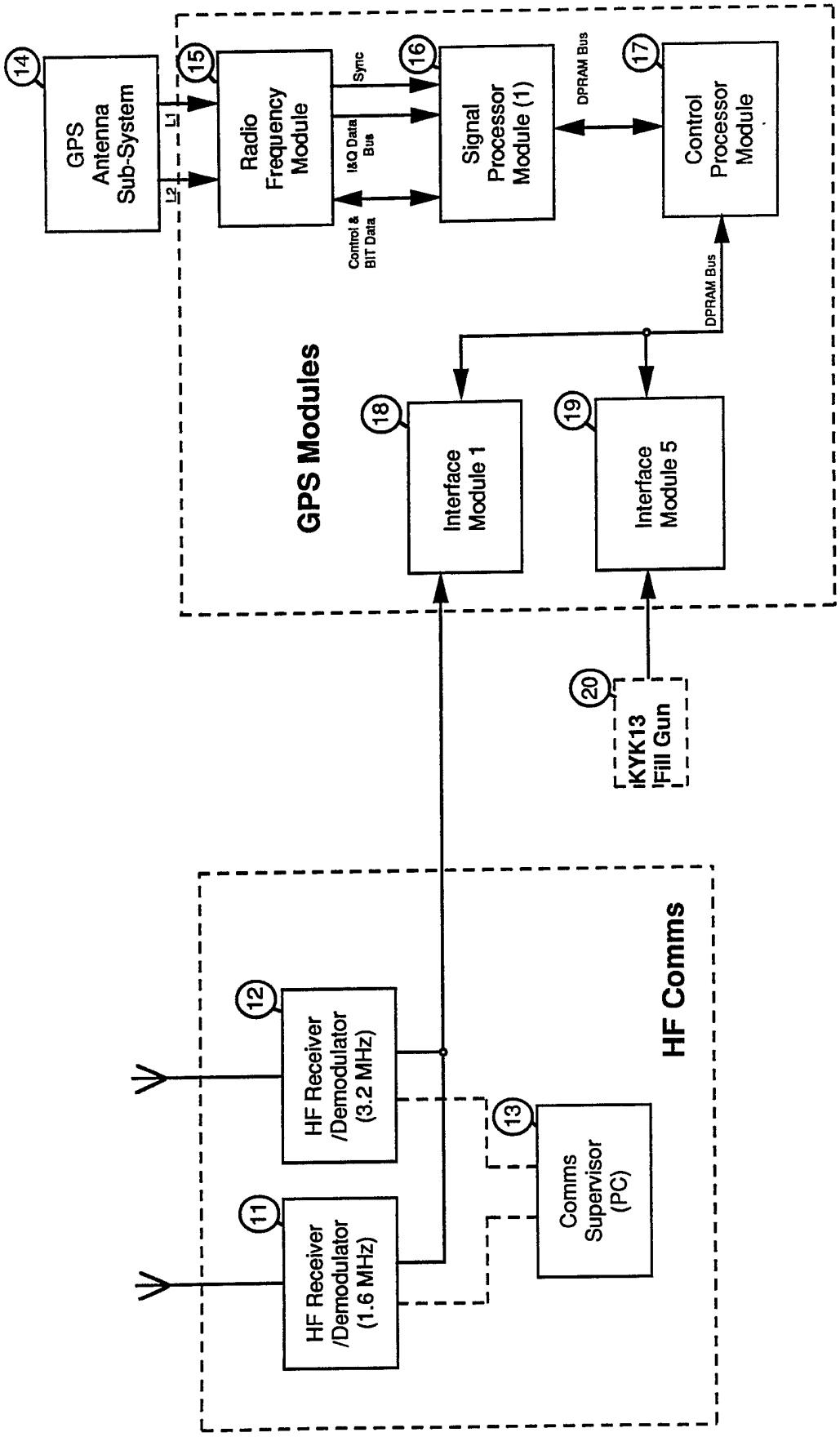
GPS Modules
14
GPS Antenna Sub-System
L1
L2
15
Radio Frequency Module
Sync
I&Q Data Bus
Control & BIT Data
16
Signal Processor Module (1)
DPRAM Bus
17
Control Processor Module
DPRAM Bus
18
Interface Module 1
19
Interface Module 5
20
KYK13 Fill Gun
HF Comms
12
HF Receiver /Demodulator (3.2 MHz)
11
HF Receiver /Demodulator (1.6 MHz)
13
Comms Supervisor (PC)

Figure 1.

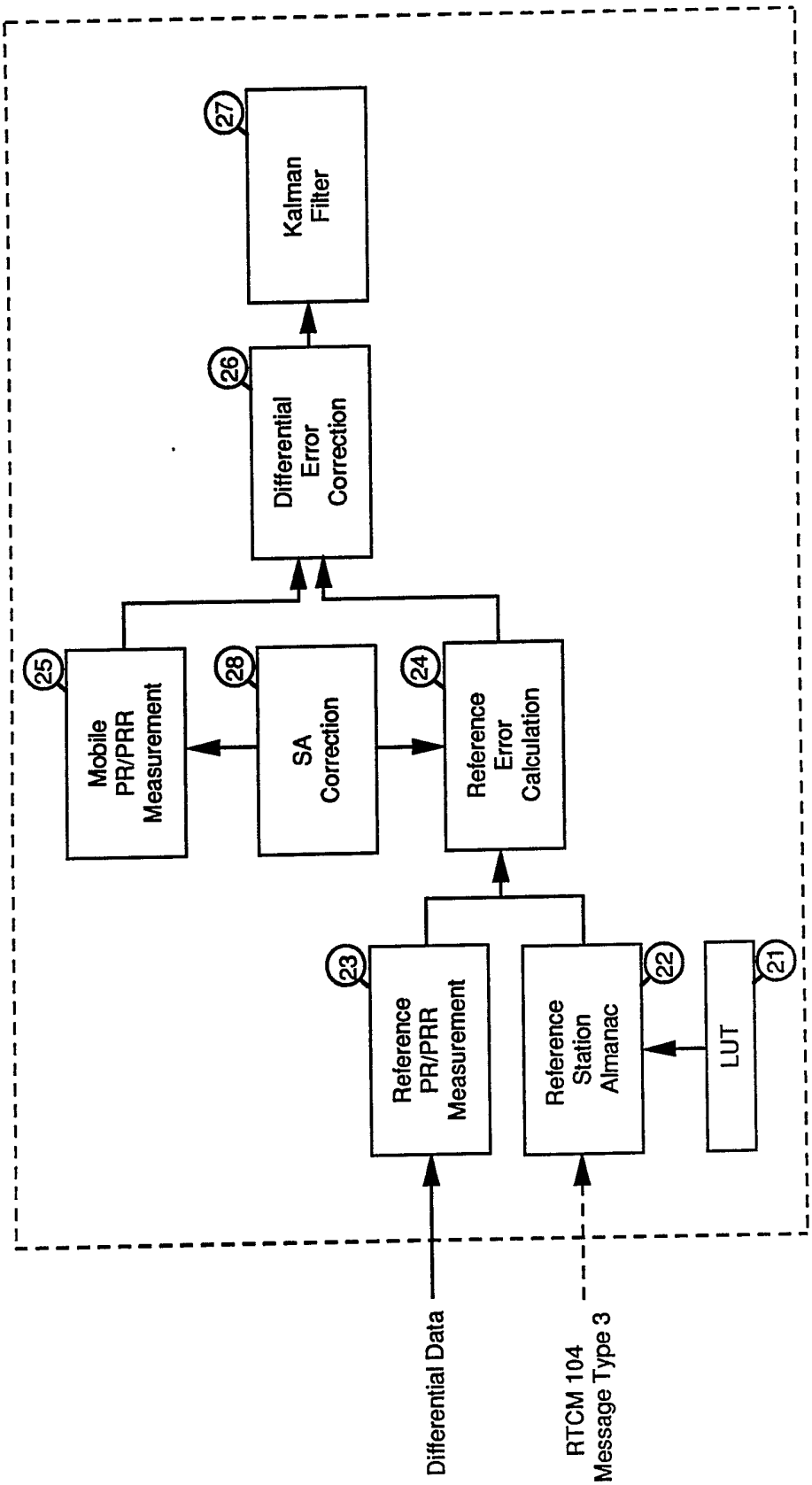
27
Kalman Filter
26
Differential Error Correction
25
Mobile PR/PRR Measurement
28
SA Correction
24
Reference Error Calculation
23
Reference PR/PRR Measurement
22
Reference Station Almanac
21
LUT
Differential Data
RTCM 104 Message Type 3

Figure 2.

DIFFERENTIAL GLOBAL POSITIONING SYSTEM

The present invention relates to a global positioning system (GPS) in which radio navigation signals emitted by a number of satellite vehicles (SVs) are received by a mobile station and used to calculate the position of the mobile station.

The United States Department of Defence provides a GPS under the name NAVSTAR which gives world wide coverage and is available to commercial as well as military users. Authorized military users have full access to the system and thus can obtain a Precise Positioning Service (PPS). Other users have a lower level of access giving a Standard Positioning Service (SPS) with lower accuracy. To achieve this an encryption technique known as Anti-Spoofing is applied and users of the Precise Positioning Service require a decryption key. Also both the precise position code available to authorized users and the coarse acquisition code available to commercial users are degraded by the application of Selective Availability (SA) processing to the satellite signals to reduce the accuracy of the range measurements. The "dither" introduced by SA processing can be removed by authorized users of the precise positioning code.

A technique exists to improve the accuracy of the Standard Positioning Service, known as differential correction technique. In a differential GPS, a fixed reference station of known position compares the information provided by the GPS with the known data and generates correction terms for transmission to the mobile station, which uses them to correct the calculated position of the mobile station. Typically the messages transmitted to the mobile station by the reference station include correction terms for the range and the rate of change of range, SV constellation health data, and reference station parameters.

If such a differential correction technique were applied to a system using the Precise Positioning Service, the messages from the reference station to the

mobile station would embody precise positioning information resulting from removal of the SA or "dither" terms at the reference station and would therefore have to be protected by further encryption.

In accordance with the present invention there is provided a differential global positioning system in which radio navigation signals emitted by a plurality of satellite vehicles (SVs) are received by a reference station and a mobile station and error terms representing the difference between the calculated range of the reference station from an SV and the true range are applied to correct the calculated range of the mobile station from the SV, the navigation signals emitted by the SVs comprising a precise position code, containing SA terms, and at least the mobile station having means for deriving the precise position code, free of SA terms, characterized in that range signals are calculated at the reference station without removal of SA terms and transmitted to the mobile station together with time of measurement information, and at the mobile station the SA terms for the time at which the measurements were made are removed from the range signal, the true range of the reference station is calculated using ephemeris corrected for SA and the known position of the reference station, and error terms are calculated and applied to correct the calculated range of the mobile station.

Information as to the true position of the reference station can be stored in the mobile station or transmitted from the reference station.

The navigation signals from the SVs will also normally comprise a coarse acquisition code for the Standard Positioning Service, also containing SA terms. The range and range rate signals calculated at the reference station can be derived from either the precise position code or the coarse acquisition code.

Preferably the signals calculated at the reference station include the rate of change of the difference between calculated and true range and the mobile station removes the SA terms from those range rate

signals before they are used in the correction of the calculated range of the mobile station.

Preferably the transmission of signals from the reference station to the mobile station is effected by means of an HF communications link.

The invention will now be described in more detail with the aid of an example illustrated in the accompanying drawings, in which:-

Figure 1 is a block circuit diagram of equipment for the mobile station of a system in accordance with the invention, and

Figure 2 is a block diagram of the differential correction process effected by the apparatus of Figure 1.

In the system in accordance with the invention the reference station serves as a range measurement facility, the sole function of which is to make instantaneous time-tagged measurements of range. No correction activity is made at the reference station. In the example to be described the information transmitted to the mobile station by the reference station comprises the reference station identity, the SV tracked, a pseudo range estimate, a pseudo range rate estimate and the time of measurement. The range and range rate signals are estimates because they are calculated from the radio navigation signals and do not rely on the true position of the reference station. They are "pseudo" because they are uncorrected and include all the SA terms. The information is received at the mobile station (Figure 1) by an HF Communications Module 10 which comprises two HF Receiver/Demodulator units 11 and 12 operating at 1.6 MHz and 3.2 MHz respectively under the control of a communications supervisor unit 13.

The mobile station has its own conventional GPS Antenna Sub-System 14 providing inputs L1 and L2 to a radio-frequency module 15 which in turn feeds data by way of a signal processor module 16 to a control processor module 17. The processor module 17 also receives, via an interface module 18, the information from the reference station received by the communications module 10. An

interface module 19 transmits to the processor module 17 the crypto-variable key input from a KYK13 fill gun 20. This allows the mobile station access to PPS data and the SA correction function.

Referring now to Figure 2, the control processor module 17 effects the successive calculations shown in this diagram. Information as to the reference station location is provided either by RTCM message type 3, which is an industry protocol for differential GPS, or from a look-up table 21, and provides the basis for the reference station almanac 22. The differential data from the reference station is used at 23 to compute the pseudo range and pseudo range rate for the reference station. These are then combined with the true position and time information to effect the reference error calculation 24.

The mobile station, through its GPS modules, has access to all the PPS data necessary to calculate a position and a velocity and thus can effect the pseudo range and pseudo range rate measurement 25 for the mobile station. These estimates are then subjected to differential error correction 26 by the application of the range correction from 24. The correction is derived according to the formula

$$R_{COR} = R_{REF} - R_{RT} - R_{RSA}$$

Where,

R_{COR} = Reference Station Range Correction
R_{REF} = Reference Station Range Measurement
R_{RT} = Reference Station True Range
R_{RSA} = Reference Station SA "dither" correction

The true range R_{RT} is calculated by using ephemeris received by the mobile station and corrected for SA in order to give the true position of the SV. The R_{RSA} term is given by the SA correction 28 for the time at which the reference station measurements were made. This allows for the delay in the measurement, computation and transmission of the reference information to the mobile station. The SA correction 28 is also applied to the mobile station range and range rate measurements 25.

Following the differential error correction 26 the corrected range and range rate information is processed by a Kalman filter 27 and used for determination of position, velocity etc. in the conventional manner. Specifically the information can be used for position determination of any mobile object, whether airborne, naval, space or terrestrial and for navigation including obstruction warning.

CLAIMS:

1. A differential global positioning system in which radio navigation signals emitted by a plurality of satellite vehicles (SVs) are received by a reference station and a mobile station and error terms representing the difference between the calculated range of the reference station from an SV and the true range are applied to correct the calculated range of the mobile station from the SV, the navigation signals emitted by the SVs comprising a precise position code, containing SA terms, and at least the mobile station having means for deriving the precise position code, free of SA terms, characterized in that range signals are calculated at the reference station without removal of SA terms and transmitted to the mobile station together with time of measurement information, and at the mobile station the SA terms for the time at which the measurements were made are removed from the range signal, the true range of the reference station is calculated using ephemeris corrected for SA and the known position of the reference station, and error terms are calculated and applied to correct the calculated range of the mobile station.

2. A system as claimed in claim 1 wherein the mobile station has stored information as to the true location of the reference station.

3. A system as claimed in claim 1 or 2 in which the signals calculated at the reference station include the rate of change of the difference between calculated and true range and the mobile station removes the SA terms from those range rate signals before they are used in the correction of the calculated range of the mobile station.

4. A system as claimed in any of the preceding claims including an HF communications link for transmitting signals from the reference station to the mobile station.

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number

Relevant Technical fields

(i) UK Cl (Edition M) H4D (DPBC)

(ii) Int Cl (Edition 5) G01S (5/14)

Search Examiner

KEN LONG

Databases (see over)

(i) UK Patent Office

(ii) Online databases: WPI

Date of Search

27 MAY 1994

Documents considered relevant following a search in respect of claims 1 to 4

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
A	GB 2,264,837 A (KOKUSAI) see particularly page 1 line 16 to page 3 line 6	-
A	EP 0,574,009 A2 (TOKYO COSMOS) see particularly column 8 line 51 to column 10 line 58	-
A	US 4751512 (OCEANONICS) see particularly column 5 line 48 to column 6 line 23	-

Category	Identity of document and relevant passages	Relevant to claim(s)
	-8-	

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family, corresponding document.

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