



US005774829A

United States Patent [19]

[11] Patent Number: **5,774,829**

Cisneros et al.

[45] Date of Patent: **Jun. 30, 1998**

- [54] **NAVIGATION AND POSITIONING SYSTEM AND METHOD USING UNCOORDINATED BEACON SIGNALS IN CONJUNCTION WITH AN ABSOLUTE POSITIONING SYSTEM**
- [75] Inventors: **Joseph S. Cisneros**, San Dimas; **David C. Kelley**, Covina; **Michael Kiang**, Aliso Viejo; **Louis A. Greenbaum**, Redondo Beach, all of Calif.
- [73] Assignee: **Pinterra Corporation**, Garden Grove, Calif.
- [21] Appl. No.: **570,747**
- [22] Filed: **Dec. 12, 1995**
- [51] Int. Cl.⁶ **G01S 5/02; H04B 7/185**
- [52] U.S. Cl. **701/213; 342/457; 701/214**
- [58] Field of Search **364/449.8, 449.95, 364/449.1, 460, 452; 342/357, 457; 340/995; 701/214, 216, 207, 300, 219**

“A Novel Procedure for Assessing the Accuracy of Hyperbolic Multilateration Systems”; H.B. Lee; IEEE, Vol. AES-11, No. 1, Jan. 1975; pp. 2-14.
 “Accuracy Limitations of Hyperbolic Multilateration Systems”; H.B. Lee; IEEE, Vol. AES-11, No. 1, Jan. 1975; pp. 16-29.

(List continued on next page.)

Primary Examiner—Michael Zanelli
Attorney, Agent, or Firm—Gary S. Williams; Flehr Hobbach Test Albritton & Herbert LLP

[57] ABSTRACT

A navigation system in which an uncoordinated beacon positioning system (UBS) is used in conjunction with an absolute positioning system (APS) is described herein. The UBS employs a multiplicity of transmitters, at known locations, each of which transmits a beacon signal having a phase that is at least partially un-synchronized with the phases of the beacon signals of the other transmitters. Within a mobile unit, separate receivers are provided for receiving these beacon signals and for receiving APS signals. The absolute positioning system (APS) receiver is disposed to receive the APS signals, and to estimate an initial position of the mobile unit therefrom. The mobile unit processor is disposed to modify the estimated mobile unit position on the basis of the detected beacon signal phases. The mobile unit processor may also be programmed to determine the uncertainty of location information provided by the beacon signal receiver and by the APS receiver. This allows the current location of the mobile unit to be updated by selecting the location estimate having associated therewith the least amount of location uncertainty, or by weighting each estimate based on its uncertainty and combining the two weighted location estimates. In another implementation, the mobile unit includes an estimator operative to compute an estimate of mobile unit position on the basis of selected pseudorange measurements from the UBS and APS receivers. The estimator may include a Kalman filter configured to process residual pseudorange information provided by the UBS and APS receivers.

[56] References Cited

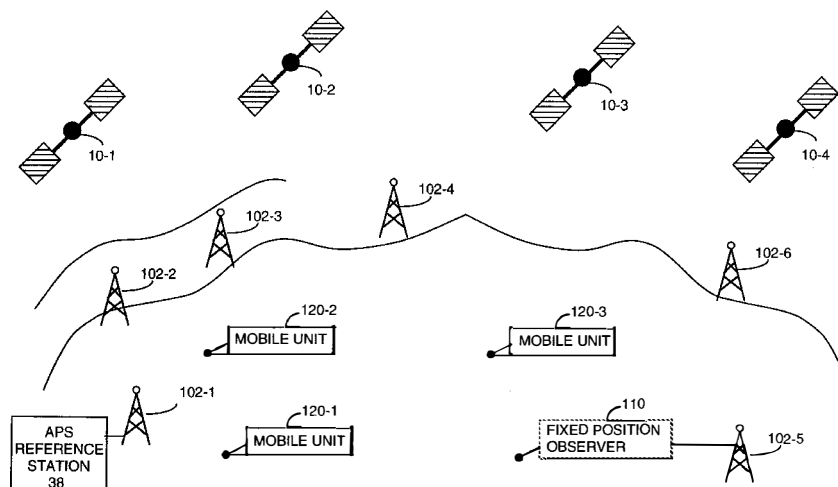
U.S. PATENT DOCUMENTS

3,774,215	11/1973	Reed	343/112 D
4,506,228	3/1985	Kammeyer	329/107
5,173,710	12/1992	Kelly et al.	342/463
5,280,295	1/1994	Kelly et al.	342/463
5,311,195	5/1994	Mathis et.	342/357
5,323,163	6/1994	Maki	342/357
5,355,526	10/1994	Berninger	455/161.2
5,365,450	11/1994	Schuchman et al.	364/449
5,406,490	4/1995	Braegas	364/449
5,422,813	6/1995	Schuchman et al.	364/449
5,499,032	3/1996	Kelly et al.	342/357
5,510,801	4/1996	Engelbrecht et al.	342/457
5,552,772	9/1996	Janky et al.	340/573

OTHER PUBLICATIONS

“A New Approach to Geometry of Range Difference Location”; R.O. Schmidt; IEEE, vol. AES-8, No. 6, Nov. 1972; pp. 821-835.

36 Claims, 16 Drawing Sheets



OTHER PUBLICATIONS

- “The Theory of Loran-C Ground Wave Propagation—A Review”; S.N. Samadhar; *Navigation*, vol. 26, No. 3, Fall, 1979; pp. 173–187.
- “Omega Possibilities: Limitations, Options, and Opportunities”; E.R. Swanson; *Navigation*, vol. 26, No. 3, Fall 1979; pp. 188–202.
- “Sensitivity of GPS Acquisition to Initial Data Uncertainties”; C.A. Smith et al.; *Inst. of Navigation, Papers Published in Navigation*, vol. 1, copyright 1980; pp. 31–43.
- “Operational Benefits and Design Approaches for Combining JTIDS and GPS Navigation”; Walter R. Fried; *Inst. of Navigation, Papers Published in Navigation*, vol. ; Jan. 1984; pp. 209–225.
- “The Impact of Cross-Rate Interference on LORAN-C Receivers”; M.J. Zeltser et al.; *IEEE vol. AES-21*, No. 7, Jan. 1985; pp. 36–46.
- “An Algebraic Solution of the GPS Equations”; Stephen Bancroft; *IEEE*, vol. AES-21, No. 7, Jan. 1985; pp. 56–59.
- “Navigational Coordinate Systems: How To Get Your Surface and Air Positioning Very Precise and Still Be Off By 20 Nautical Miles”; Stephen B. Richter et al.; *IEEE* 1986; pp. 268–272.
- “Combining LORAN and GPS—The Best of Both Worlds”; Paul Raisted et al.; *Inst. of Navigation, Papers Published in Navigation*, vol. III; copyright 1986; pp. 235–240.
- “Terrestrial Evaluation of the GPS Standard Positioning Service”; Francis W. Mooney; *Inst. of Navigation, Papers Published in Navigation*, vol. III; copyright 1986; pp. 275–293.
- “Telenav: A Precision Navigation System Based Upon Television Signal Reception”; Will Connelly; *Navigation*, vol. 33, No. 2, Summer 1986; pp. 109–122.
- “A Direct Solution to GPS-Type Navigation Equations”; Lloyd O. Krause; *IEEE vol. AES-23*, No. 2; Mar. 1987; pp. 225–232.
- “Passive Source Localization Employing Intersecting Spherical Surfaces from Time-of-Arrival Differences”; H.C. Schau et al.; *IEEE vol. ASSP35*, No. 8, Aug. 1987; pp. 1223–1225.
- “Aircraft Experiences with a Hybrid Loran-GPS”; Ralph Eschenbach et al.; *Navigation*, vol. 35, No. 4; Winter 1988–89; pp. 459–468.
- “Aiding GPS with Calibrated Loran-C”; Per K. Enge et al.; *Navigation*, vol. 35, No. 4; Winter 1988–89; pp. 469–482.
- “Cost Effective, High-Accuracy Inertial Navigation”; A Matthews et al.; *Navigation*, vol. 36, No. 2; Summer 1989; pp. 157–172.
- “A Divide and Conquer Approach to Least-Squares Estimation”; *IEEE Transactions Aerospace & Electronic Syst.*, vol. 26, No. 2; Mar. 1990; pp. 423–426.
- “Synergistic Integration of GPS and INS for Civil Aviation”; John Diesel et al.; *GPS World*; May 1991; pp. 41–45.
- “A Rate Integrating Fiber Optic Gyro”; *Navigation*, vol. 38, No. 4; Winter 1991–92; pp. 341–353.
- “Urban Positioning with GPS: A Mobile Communications Field Measurement Application”; Jean-Claude Fantou; *GPS World*; Jul. 1993; pp. 28–39.
- “Integration of GPS with Inertial Navigation Systems”; D.B. Cox, Jr.; *Inst. of Navigation, Papers Published in Navigation*, vol. III, copyright 1986; pp. 144–153.
- “Integration of GPS and Dead-Reckoning Navigation Systems”; Wei-Wen Kao; pp. 1–9. No Date.

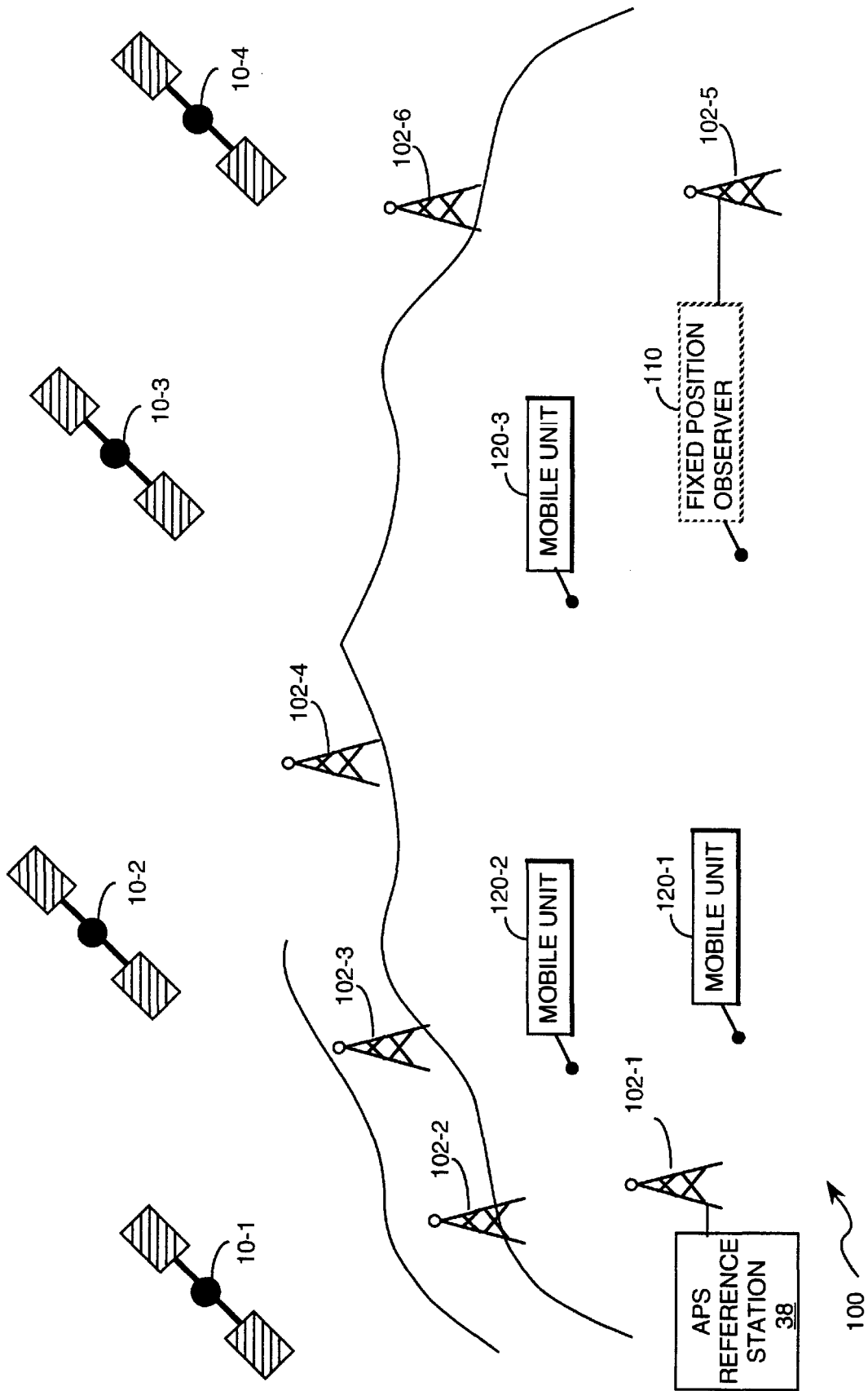


FIGURE 1

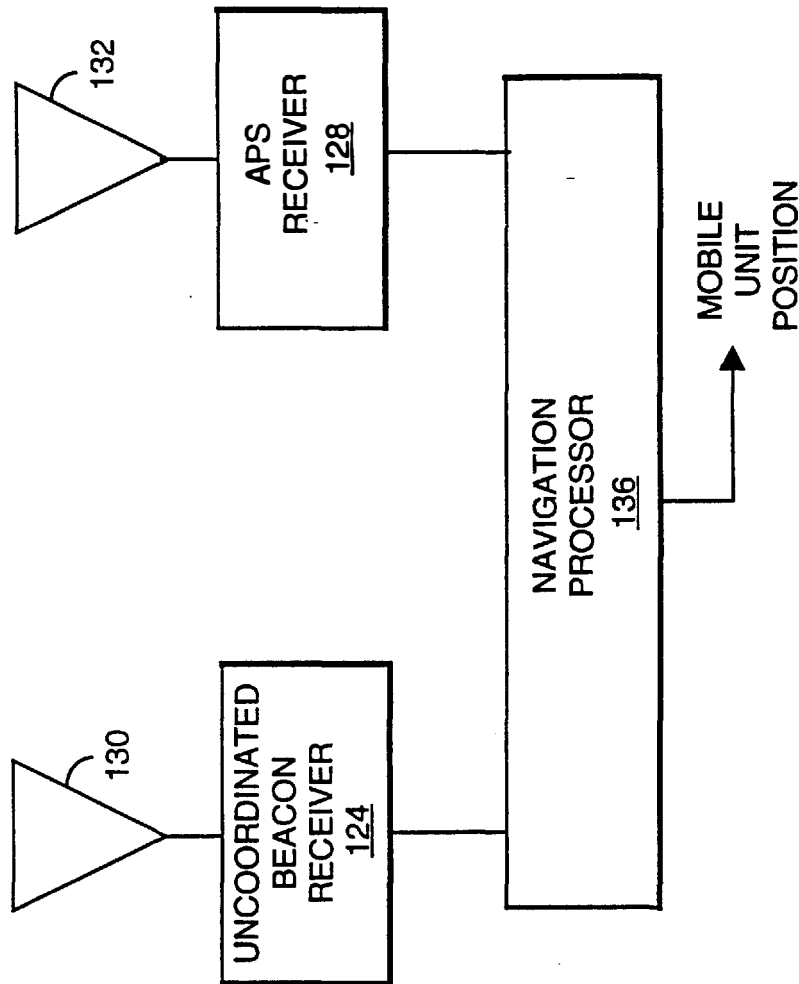


FIGURE 2A

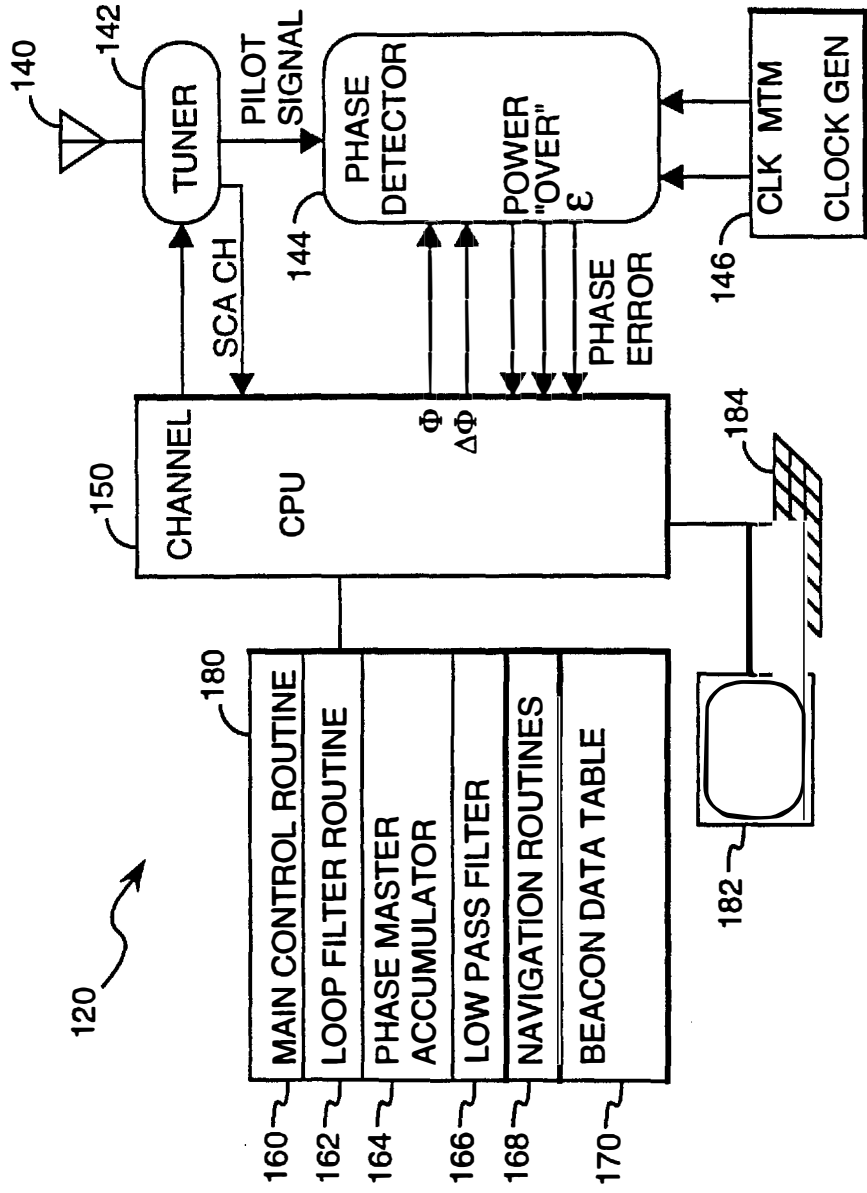


FIGURE 2B

Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts



Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research



With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips



Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.