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United States Patent [19]

Gnatjuk

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[54] **AUTONOMOUS ON-BOARD SATELLITE CONTROL SYSTEM**

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[51] **Int. Cl.⁶** **B64G 1/24**

[52] **U.S. Cl.** **244/164**

[58] **Field of Search** 244/164–171

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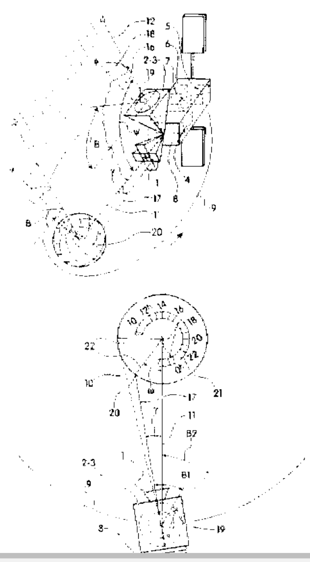
Primary Examiner—Galen L. Barefoot

Attorney, Agent, or Firm—Collard & Roe, P.C.

[57] **ABSTRACT**

An autonomous on-board satellite control system is to achieve autonomous orientation control and autonomous determination of the satellite's altitude and location in relation to the Earth's longitude and latitude grid. This is done with the aid of the following elements: an Earth sensor (**1**), a Pole-star sensor (**2**), a computer (**4**), a timing device (**6**) and actuator units (**7**). The system also includes a navigational star sensor (**3**) and a storage device (**5**), while the computer is designed so as to facilitate supplementary determinations. The orientation of the satellite is controlled by superimposing the general sensory plane (**16**) of the sensors (**1** and **2**) with the plane of the angle "center of Earth—satellite—Pole star" which defines latitude. The geovertical (**11**) rotates about a line to the Pole star (**12**) as the satellite (**8**) moves in its orbit (**9**) and this is equivalent to the revolution of the stars in the field of vision of the sensors (**2** and **3**). The rotation of the plan containing the lines to the stars (**12** and **18**) is measured in relation to a reference line (**19**) whose longitude and angular parameter ("B") are kept in the storage device (**5**). Inertial longitude is calculated as the sum of the angle of measurement and the right ascension of the Pole star as the base longitude and is converted to the geocentric longitude. The altitude of the plan (**16**) to the latitudinal plane is calculated as the product of the polar distance of the Pole star and the sine of the angle of measurement, while its development (γ) when in misalignment with the longitudinal axis (**17**) is calculated as the product of the angular dimension of the Earth's radius, the sine of the angle is equal to the difference in longitudes of a target point (**20**) and the point below the satellite and the cosine of the latitude angle.

4 Claims, 3 Drawing Sheets



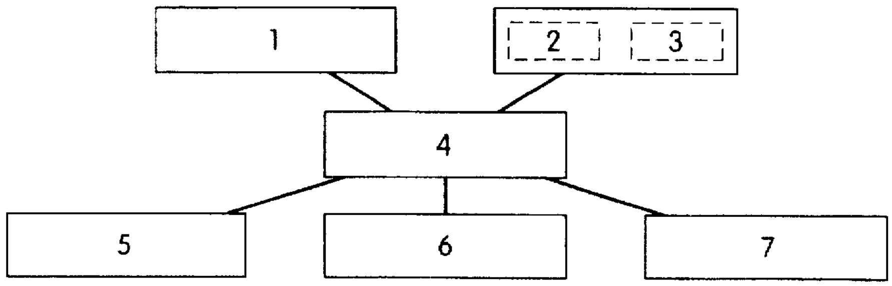


Fig. 1

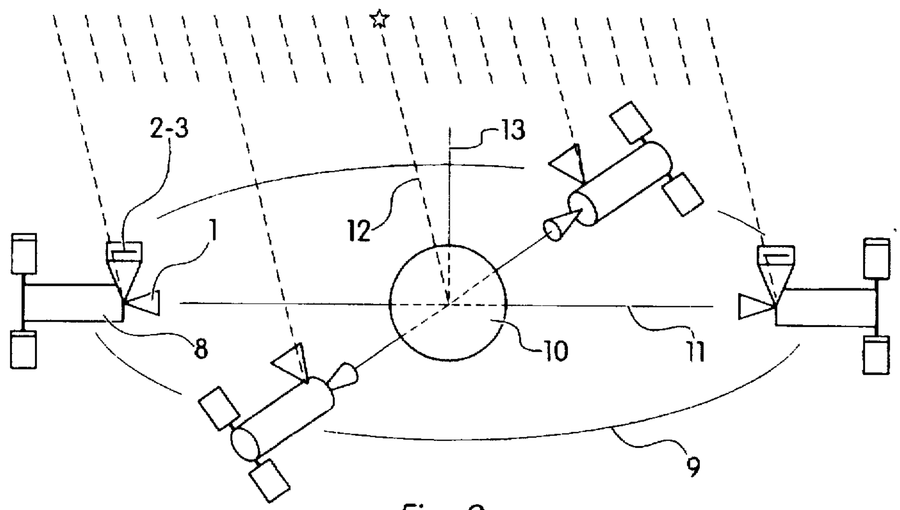


Fig. 2

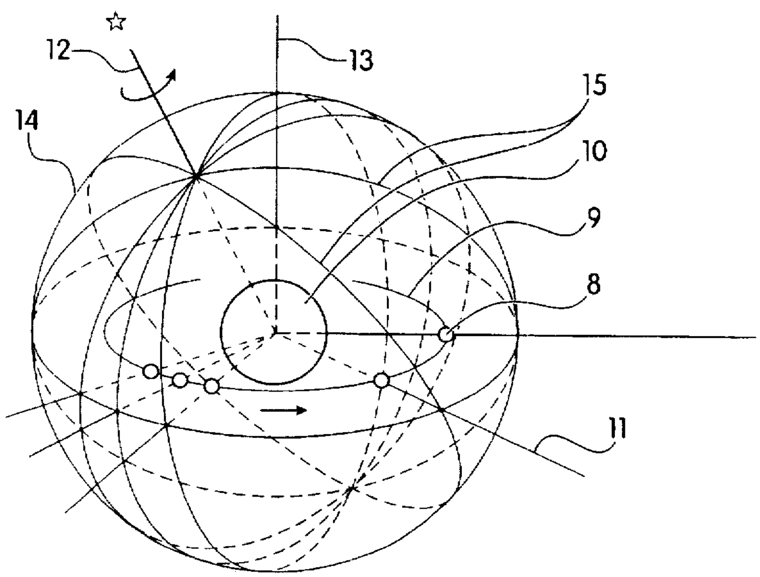


Fig. 3

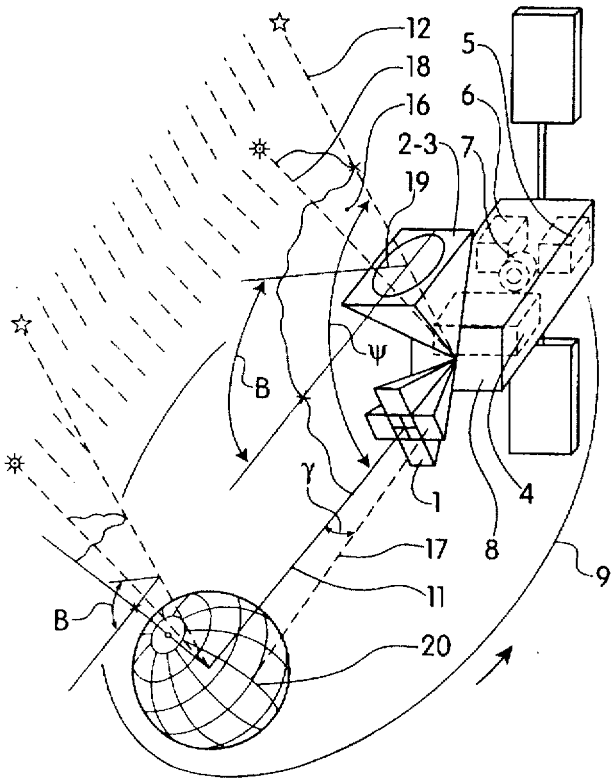


Fig. 4

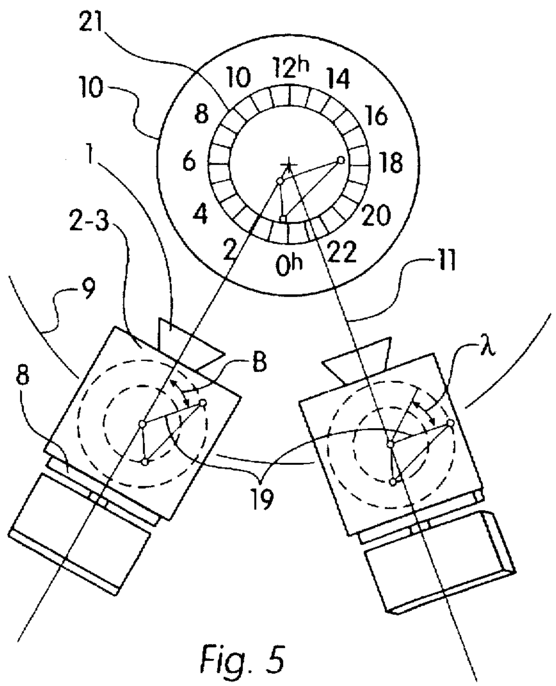


Fig. 5

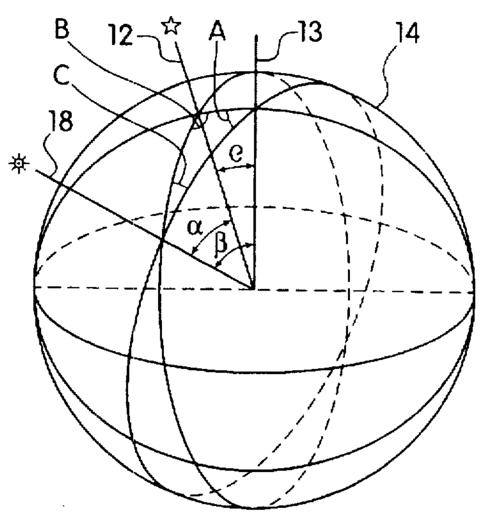


Fig. 6

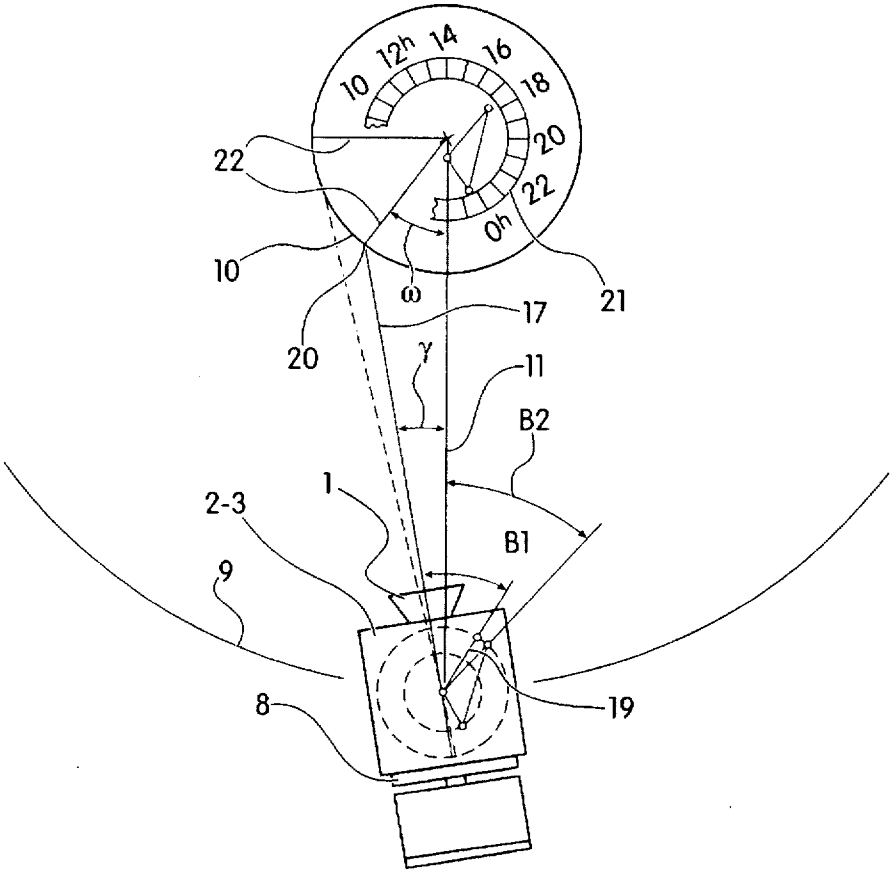

10
12h
14
16
18
20
22
0h
22
10
ω
17
21
20
γ
11
B2
1
2-3
B1
9
8
19

Fig. 7

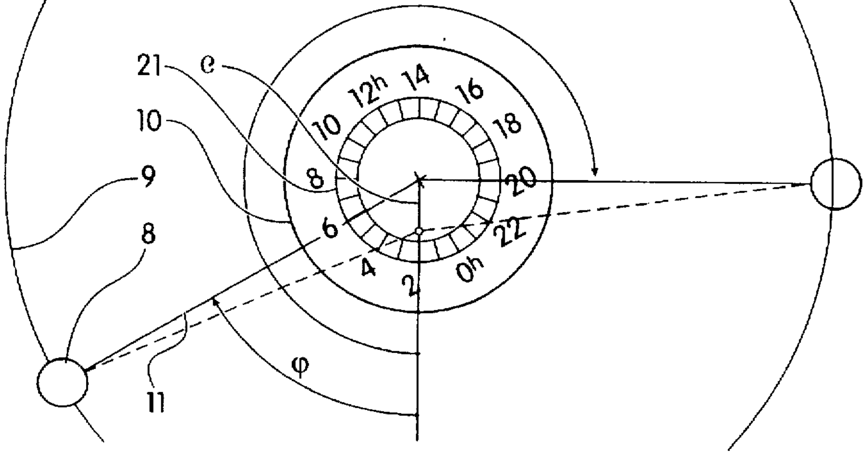

270°
21
e
10
9
8
11
φ
12h
14
16
18
20
22
0h
2
4
6

Fig. 8

AUTONOMOUS ON-BOARD SATELLITE CONTROL SYSTEM

Invention relates to astronavigation and satellite angular orientation control and is designed for using at autonomously functioning satellite. Satellite, moving in three-dimensional space has six degrees of freedom. In these environment satellite guide control is performed by navigation and orientation system with the determination of three coordinates of location point: flight longitude, latitude and altitude and three angular orientation coordinates: pitch, roll and yaw.

Active control orientation system of the geostationary satellite, being foreseen as analog, is known.(patent of France N 2637565, 1988).

Mentioned orientation control system of the satellite is characterised by the following. System includes the Earth sensor, Sun sensors, sensor of the Pole star, processing and calculation units, drive motors. System provides three-axis satellite stabilization: east-west, north-south and geocentric. The following sensors are used while orientation control:

pitch and roll: the Earth sensor;

yaw: star sensor.

These different sensors give the output signals, going into data processing networks, that are designed for correction manoeuvres amplitude determination according to this data; manoeuvres are executed by drivers of any known corresponding type (reactive flywheels, inertial flywheels and nozzles). Three satellite orientation angles, including yaw, are being constantly controlled in the working mode.

Errors of the Earth sensor could be used for pitch and roll control without preliminary processing. Angular deviations, corresponding to pitch and roll channels during measurements by the Earth sensor are considered to be equal. System is characterised also by the fact,that in its composition there is a unit, containing the Pole star location evolution model, and this unit is connected with the telemetry unit. Hence, this model parameters are being renewed periodically, basing on the information, receiving from the Earth. In order to control yaw angle, it is necessary to execute the following operations:

- basing at the ephemerids, processed by the mentioned unit, satellite location in the inertial coordinate system is calculated;
- after that, with the help of the same unit, theoretical coordinates of the Pole star in the star sensor field of view are to be calculated, while this is assumed, that the satellite has ideal orientation (pitch, yaw and roll are equal to zero),
- yaw error signal is calculated in the processing network, that is equal to the difference of the Pole star location coordinates in the two-dimensional field of view, and basing on this error, yaw control amplitude is to be calculated in order to delete having shift.

Mentioned system has the following, similar to invention, indications while the working mode providing:

- analogous devices are being used in the system: the Earth sensor, sensor of the Pole star, computer, actuator organs;
- orientation control on pitch and roll channels is provided with the help of the Earth sensor, on yaw channel—by star sensor. Foreseen as analog, mentioned system has the following demerits in the satellite angular position determining relatively to north-south axis (the Earth latitude plane):
  - system is complicated by using of the unit, containing system for renewing of the mentioned model parameters, depends on data, receiving from the Earth;
  - system needs in performing of a row of calculation operations in order to calculate the difference between real and theoretical Pole star position coordinates in the star sensor field of view.

Autonomous on-board system of orbit determination (article "Autonomous on-board orbit determination systems", Astrodynamics Conference, Aug. 20–22, 1984, Seattle, Wash.), being foreseen as a prototype, is known.

Mentioned system includes the Earth sensor, Sun sensors, the Pole star sensor,computer, mass memory device, actuator organs. The Earth sensor is pointed into nadir and it forms errors on pitch and roll for orientation control system,that keeps this direction in the limits of the central zone of non-sensitivity. Error signals are proportional to the Earth angular deviations from sensor line of sight on two across directions. Angle between the Earth sensor line of sight and the Sun sensor line of sight directions is measured by potenciometrical sensor of the panel drive-motor, installed on the panel. Angle "the Sun—object—the Earth" is the best observation for orbit determination. Information about the Sun location relatively to the Earth is taken from a file with ephemerides.

The Sun ephemerides are put into the computer as a complicated time functions. If the Sun is in the satellite orbital plane, then angle "the Sun—object—the Earth" directly characterizes true inertional longitude of the satellite. If the Sun is not in the satellite orbital plane, measurement contains some information about orbit inclination components. Best evaluation conditions of the orbit inclination vector correspond to maximal Sun declination, the worst—to zero. If the Sun declination equal to zero,orbit inclination vector components are not observed. In the case, if the angle "the Pole star—object—the Earth" is measured additionally, these components could be observed independently of the "light source" declination. In the case of determining according to the Pole star, it is considered, that additional measurements of "the Pole star—object—the Earth" angle are executed with the same frequency (1/30 min), as "the Sun—object—the Earth" base angle measurements. Integrated data, based on both measurements sequence, mattes errors to be observing. Mentioned measurements are referenced in time Information on a present satellite location could be received from the equations of satellite moving. Integration of motion equations is performed with the fixed pitch, equal to 30 minutes. 30 minutes interval was chosen from the nominal system state correction that is performed every 30 minutes.

Mentioned system has the following, similar to invention indications:

- analogous devices are being used in the system, such as: the Earth sensor, the Pole star sensor, computer, storage device, timing device, actuator units;
- determination of satellite latitude is performed by "the Earth centre—satellite—the Pole star" angle measurement;
- orientation control on pitch and roll channels is provided by the Earth sensor, on yaw channel—it is presumed the Pole star sensor using.

Foreseen as a prototype, mentioned system has the following disadvantages in satellite location parameters determination:

- Sun navigation reference point ephemerides are being input as a complicated functions of time;
- navigation measurements could not be performed continuously due to periodically satellite shadowing by the

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