ADVANCED TELEMETRY TRACKING SERVO SYSTEM

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ABSTRACT

The primary objective of the Advanced Telemetry Tracking System Integration and Development program at WSMR was the development and evaluation of an advanced, almost totally digital servo tracking and control system. This was satisfied by replacing the aging analog servo tracking and control system in one of WSMR's seven Transportable Telemetry Acquisition Systems (TTAS) with a Digital Control Unit (DCU), an Antenna Control Unit (ACU), and other related equipment, and then evaluating the performance of the resultant digital tracking system, referred to as the Advanced TTAS (TTAS-A).

The ACU is the primary interface between the operator and the DCU. Through the ACU, the TTAS-A operator has independent control over each pedestal axis (elevation and azimuth) involving the selection of tracking mode and servo bandwidth. The DCU reports various servo system status and warning conditions back to the operator through the ACU.

In this paper, a discussion of the TTAS-A servo system, with emphasis upon hardware external to the DCU, is presented. This includes the operation of servo position and rate loops, system status and warning conditions, and a description of the operator-to-system interface via the ACU display and control functions.

INTRODUCTION

The seven TTAS, produced by the Symmetrics Corporation, were acquired by WSMR in 1967, with the first being delivered in 1969. (TTAS-1 is illustrated in figure 1.) The TTAS is a self-contained, transportable, dual-axis telemetry tracking system--using, originally, a single-channel monopulse antenna feed to automatically track a moving target transmitting an S-band or L-band telemetry signal with a tracking threshold (receive level) of -120 dBm with a 100 kHz bandwidth. The tracking system can be slaved to externally derived pointing data (from a radar, for example) for initial target acquisition or reacquisition if it loses automatic track (called Autotrack), or it can be manipulated manually by an operator.

OVERVIEW OF THE TTAS SERVO SYSTEM

The TTAS-A servo system is illustrated in figure 2, which shows only one rate loop axis since each is functionally equivalent. The DCU closes the position loops for both the elevation and azimuth axes for all tracking modes and all servo bandwidths. The operator commands the DCU as to which tracking mode and servo bandwidth to use for each axis through the ACU. The three tracking modes available for each axis are Manual, Autotrack, and Digital Slave. Three servo bandwidths are also available for each axis.

Knowing which tracking mode to use, the DCU reads in the appropriate position drive command and the present position of the antenna, to determine the position error. The DCU then compensates the position error using a Proportionality-Integrator-Differentiator (PID) controller. The PID controller, illustrated in figure 3, creates a type-2 servo system for the TTAS-A because of the presence of the pure integrator within the controller. For a constant acceleration input, the servo system will attain a nonzero, steady-state position error inversely proportional to the PID integrator gain. For a constant velocity input, the steady-state position error will become zero. * After computing the PID controller output, the DCU sends the output to the rate loop using a digital-to-analog converter.

The rate loop is closed using an analog tachometer. An internal current limiting loop also exists to prevent the dc motor windings from overheating and to limit the ability of the motor to accelerate. The current loop is contained within the Pulse-width Modulated Power Amplifier (PMPA) and is set to limit the acceleration of the antenna to a maximum of 120 degrees/second^2 in each axis. The motor, coupled to the antenna through a 420:1 gearbox, turns much faster. The PMPA output saturates at a maximum of 150V dc. At saturation, the antenna reaches a maximum velocity of approximately 45 degrees/second in each axis.

The position loop feedback exists in two forms. First, the DCU can monitor the actual position of the antenna through a synchro and synchro-to-digital converter (SDC). The other method involves the conical scanning antenna feed which produces an amplitude modulated radio frequency (RF) signal if the antenna is not pointing directly at the RF transmission source. The azimuth and elevation tracking position error signals are derived by demodulating the amplitude modulated RF with the appropriate scan reference signal, also originating from the feed. If the operator selects either the Digital Slave or Manual tracking modes, the DCU closes the servo position loop, using the SDC feedback. The

*Hart, Michael J., A Computer controlled Type-2 Telemetry Tracking System, International Telemetry Conference Proceedings, Vol XXVI, International Foundation for Telemetering, Las Vegas, NV 1990, pp. 217-232.

tracking error signals, originating from the antenna feed, are used to close the servo position loop--if the operator selects the Autotrack tracking mode.

SYSTEM WARNING AND STATUS CONDITIONS

Figure 2 does not completely illustrate the operation of the rate loop. Contained within the rate loop are several system warning and status conditions concerned with the physical limitations of the pedestal and several switching functions. These are illustrated more fully in figure 4, which shows only one axis since each is functionally equivalent.

The first status condition is pedestal power. Pedestal power is toggled by the operator, and its status is monitored by the DCU. The DCU has no control over pedestal power. When pedestal power is engaged, the operator is actually only turning on power to two blowers inside the pedestal, which cools the motors. If the blowers are working properly, they close two pressure switches that are connected in a series. When closed, the pressure switches turn on the main power relay to supply power to the power amplifiers and other rate loop equipment. The pressure switches are known collectively as the Blower Interlock. The DCU monitors the Blower Interlock status and reports it to the operator through the ACU. If the Blower Interlock is not on when pedestal power is on, the servo system will not function, and the DCU will inhibit the Drive On mode.

Another interlock in the TTAS rate loop is the Brake Interlock. There is one Brake Interlock for each axis. Both the elevation and azimuth axes can be mechanically stowed through the use of two stow pins. Prior to operating the TTAS, the stow pins must be removed from their stowing positions and be inserted into two receptacles attached to the pedestal brakes. When this action is taken, the brake on each axis is engaged, and interlock switches within the brake stow pin receptacles are toggled. Each interlock switch closes a Brake Interlock line monitored by the DCU. Like the Blower Interlock, if the Brake Interlock is not activated in one of the axes, the servo system will not function in that axis.

When either axis of the TTAS servo system is not active, that particular axis is in the Standby mode. To activate either axis of the servo system, the operator must select the Drive On mode by pressing the appropriate switch on the ACU front panel. If pedestal power has not been turned on, or if either the Blower Interlock or the Brake Interlock, or both, have not been activated, the DCU will prevent the operator from activating the servo system by keeping that particular axis in the Standby mode.

When one of the servo system axes is activated in the Drive On mode, the DCU closes a two-pole relay causing two actions simultaneously; the brake of that axis is released electronically, and the rate loop is closed with the connection of the PMPA output to the armature of the drive motor. In the Drive On mode, the operator can select one of the three operational tracking modes and one of the three servo bandwidths for each axis.

When the servo system is in the Drive On mode, the DCU and the operator must be observant of several conditions; the travel limits of each axis and the Azimuth Cable Wrap. The antenna in the elevation axis can move freely between -10 and 90 degrees; in the azimuth axis, it can move between -360 and +360 degrees. At both extremes of each axis, there is a set of three travel limit switches; they are named, from least to most extreme, Rate, Servo and Electrical Limits. When the first of the three limit switches (the Rate Limit switch) is activated, the DCU notifies the operator of the limit condition by activating the appropriate warning indicator on the ACU front panel, and by activating an audible alarm. The DCU also reduces the maximum drive output to the rate loop, to reduce the maximum velocity of the antenna while it is in the limit condition. If the antenna continues to move beyond the Rate Limit and activates the Servo Limit switch, the DCU will no longer allow the operator to drive the antenna in the direction of the limit. If the antenna had been traveling at a high velocity, and reaches the Electrical Limit, the DCU will place that axis into the Standby mode to open the rate loop and engage the brake. While in the Electrical Limit, the DCU will permit the operator to place the servo system in the Drive On mode to drive the antenna in the direction out of the limit condition.

The azimuth travel limit switches, alone, are incomplete indicators regarding the limitations of the azimuth axis since they only indicate an extreme condition. As illustrated in figure 1, the elevation axis of the TTAS pedestal rides atop the azimuth axis. All of the RF and elevation servo control cabling, terminating in the upper elevation half of the pedestal, twists as the azimuth axis is rotated. Since the azimuth axis can travel 720 degrees, the amount of cable twisting must be continuously monitored by the DCU and the operator, to insure the protection of the cabling. This is referred to as the Azimuth Cable Wrap. The DCU monitors the Azimuth Cable Wrap through a potentiometer whose shaft is connected to the azimuth axis, and reports its status to the operator through the ACU. Zero cable wrap is the center point where the azimuth axis can travel 360 degrees in either direction.

THE ANTENNA CONTROL UNIT

The ACU was designed to be similar to control panels already in use at WSMR on other telemetry tracking systems and is illustrated in figure 5. It is the primary interface between the operator and the DCU. For the most part, all functions associated with the elevation axis are on the left-hand side of the front panel, and all functions associated with the azimuth axis are on the right-hand side. The left-hand and right-hand sides of the front panel are mirror images of each other.

The position of the antenna is displayed in the center of the panel, using 1-inch height seven-segment LED displays. These displays are accurate to 0.1 degrees. The tracking mode select switches are below the position displays. The operator can select one of the three tracking modes: Manual, Digital Slave, or Autotrack. Both the Digital Slave and Autotrack select switches contain valid indicators to inform the operator that these tracking modes can be engaged. The Autotrack valid indicator will illuminate when the received signal strength from the RF source is greater than a preset signal strength threshold. The Digital Slave valid indicator will illuminate when a valid external pointing data message exists. Two extra switches for each axis were placed here for a fourth tracking mode, Synchro Slave, which was later deleted when it was no longer required.

Immediately below the tracking mode select switches are the servo bandwidth switches labeled Low, Medium and High. Only one of the three switches in each axis can be selected at one time. Below these are the Standby and Drive On select switches. In the two lower corners of the panel are two 10-bit digital encoders, used for moving the antenna in the Manual tracking mode.

Above the position displays are three analog zero-centered edgewise meters. The two outer meters display the elevation and azimuth Autotrack tracking error. These meters can also display the Digital Slave tracking error if the button on the bottom left of the panel is pressed. The central analog meter displays the Azimuth Cable Wrap.

Above the analog meters, the switches and indicators are used primarily for the pedestal status and warning conditions. The two outermost buttons are the alarm override switches. Next to these are the split-legend indicators which display the status of the rate travel limit switches. Next to these approaching the center of the panel are the Forced Auto Select switches which the operator can select to override the validity of the Autotrack tracking mode.

The indicator immediately to the right of center at the top of the panel has a split legend. The top legend displays the status of the Blower Interlock. The lower legend displays the DCU Remote condition, which illuminates when the DCU is controlling the tracking system through software. When the Remote condition exists, the DCU ignores all operator input from the ACU front panel. Immediately to the right of this indicator is the audible alarm which sounds when an antenna travel limit has been reached in either axis.

In the center of the ACU front panel are two potentiometers which the operator uses to adjust the signal strength thresholds for both left-hand circular polarization (LHCP) and right-hand circular polarization (RHCP) reception for Autotrack validity. Below the potentiometers are valid indicators illuminating when the received signal strength in that polarization is greater than its signal threshold level. Below the valid indicators is a threeway switch where the operator chooses which polarization to use for Autotrack: LHCP, RHCP, or combined.

CONCLUSION

The incorporation of the DCU and other related hardware into the TTAS has clearly demonstrated the successful development of an improved, almost totally digital servo for use in telemetry tracking systems. The dynamic tracking capability of the TTAS has been enhanced by the type-2 PID algorithm. Through the self-diagnostic software and automated test system developed for the TTAS-A, operators will be able to quickly identify problems within the system and measure various system parameters far more efficiently.

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REFERENCE

1. Hart, Michael J., A Computer Controlled Type-2 Telemetry Tracking System, International Telemetry Conference Proceedings , Volume XXVI, International Foundation for Telemetering, Las Vegas, Nevada, 1990, pp. 217-232.

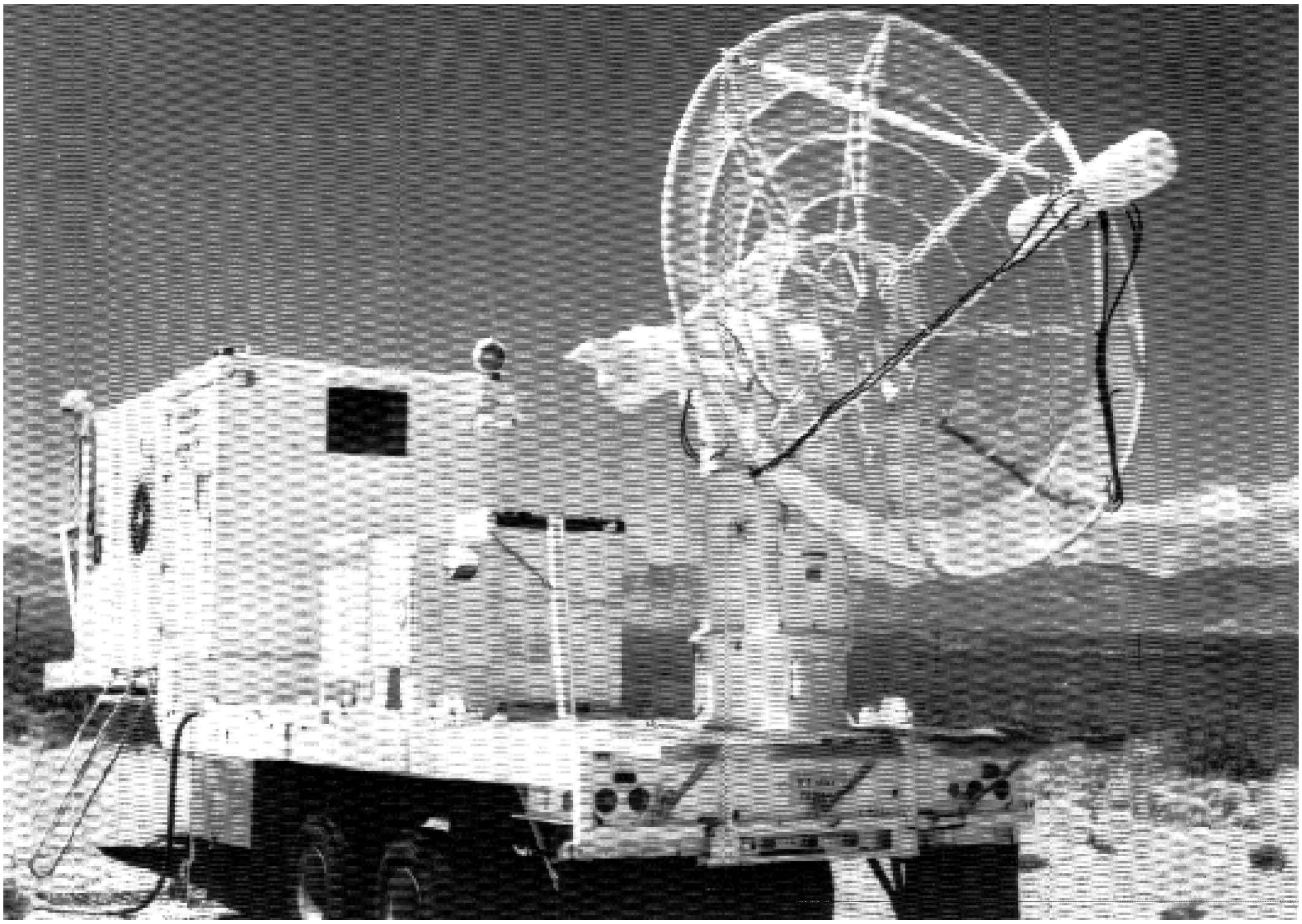

Figure 1. TTAS-1.

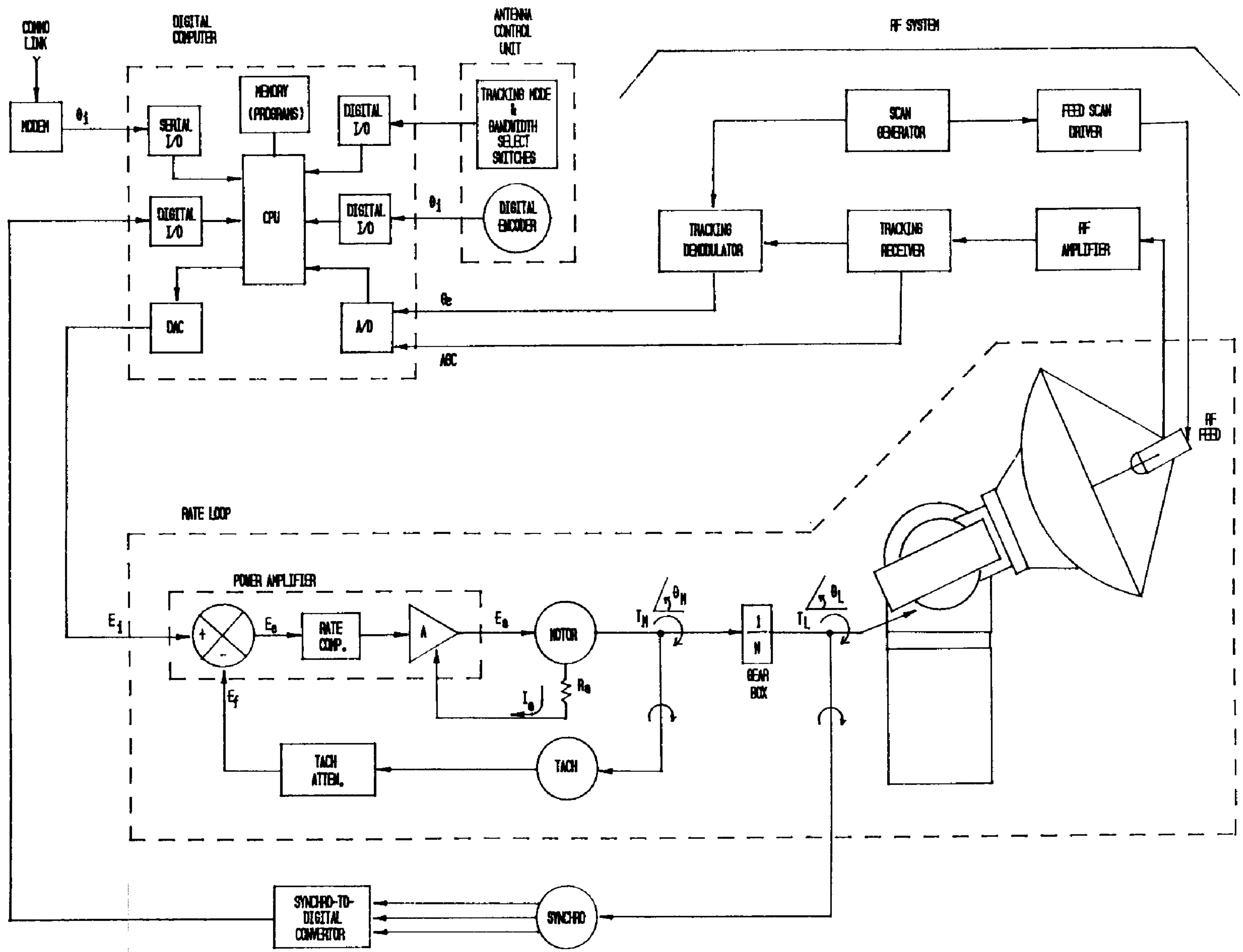

Figure 2. TTAS-A Servo Block Diagram.

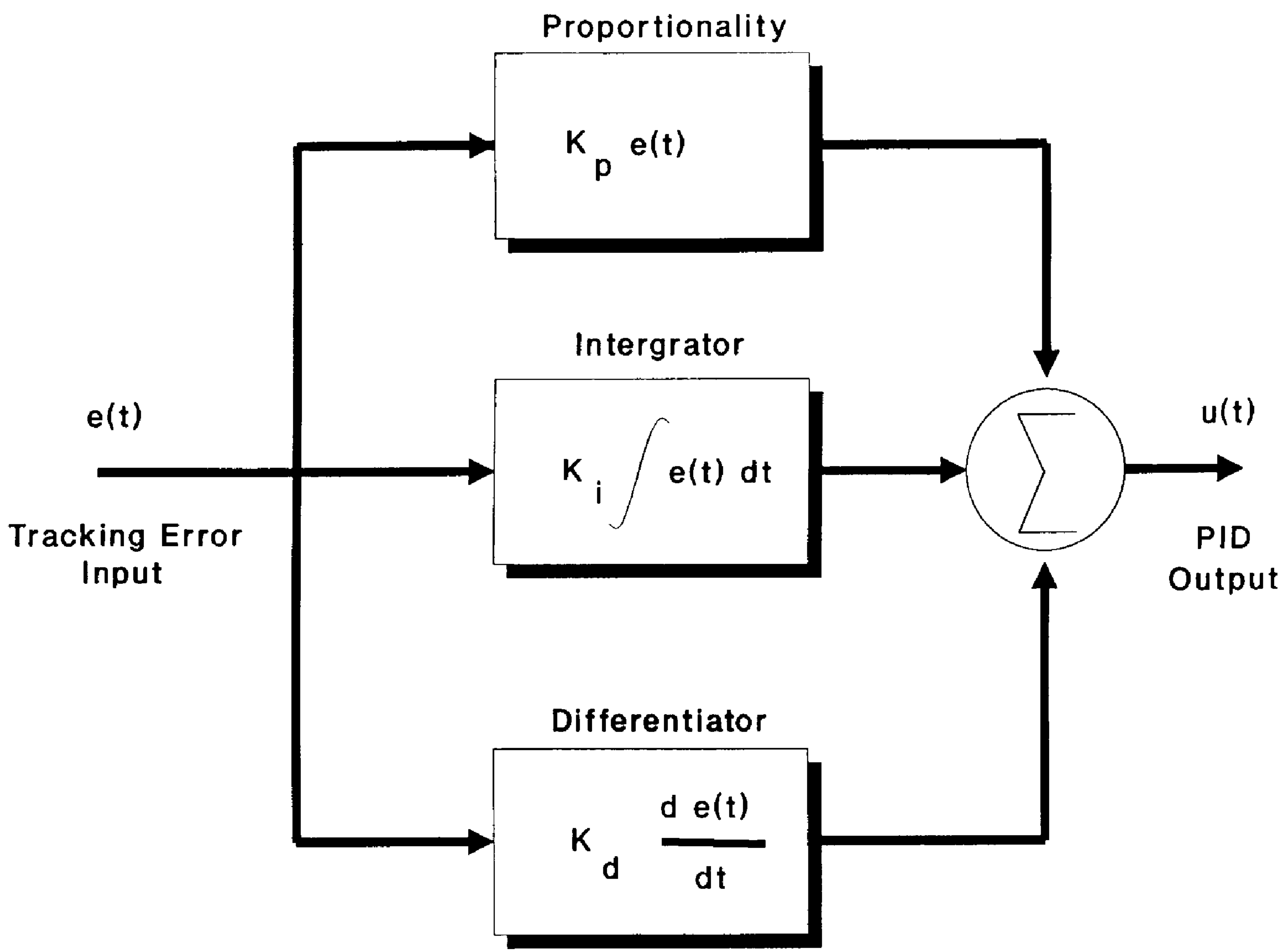

Figure 3. PID Controller.

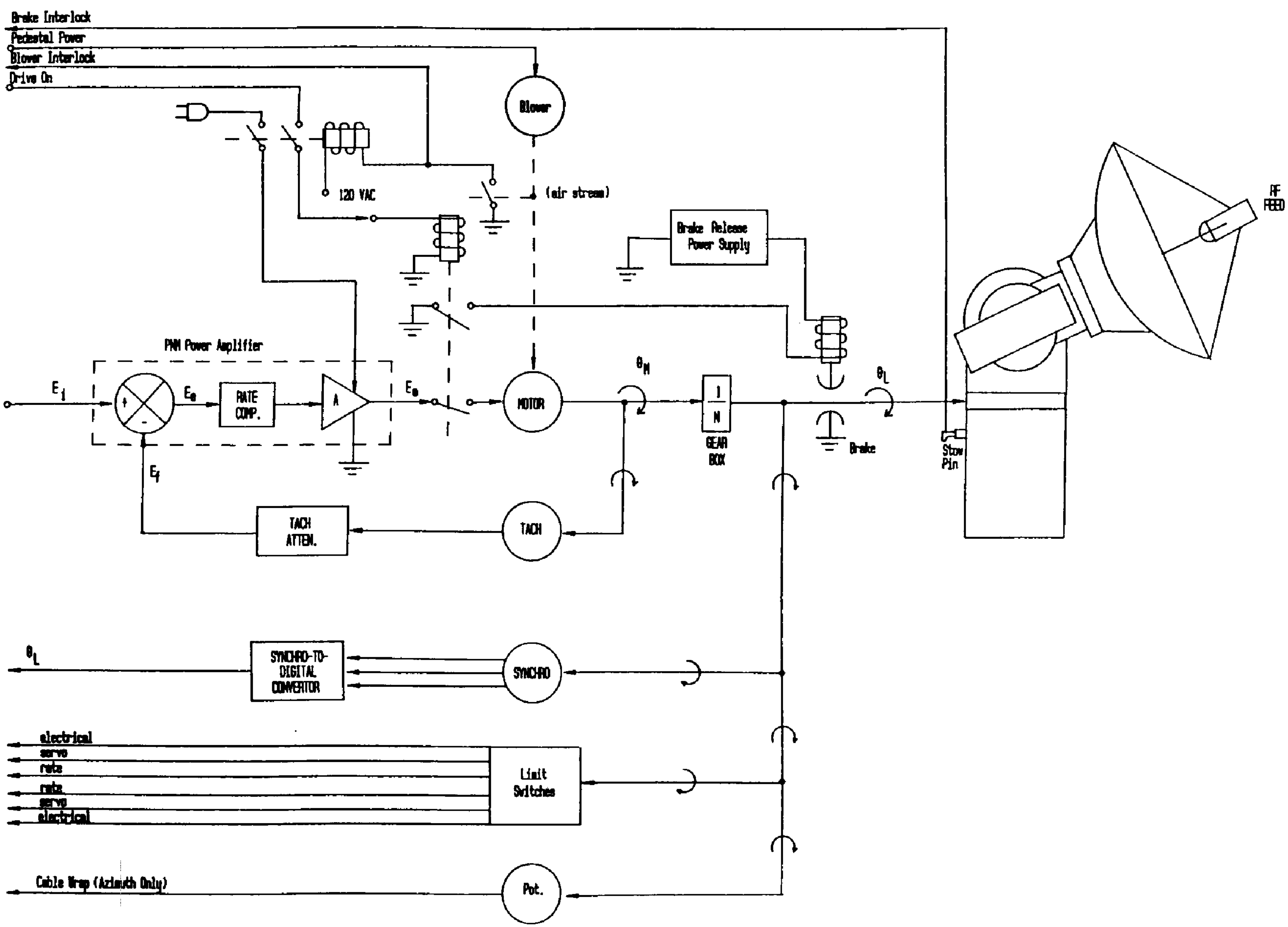

Figure 4. Detailed Rate Loop Block Diagram.

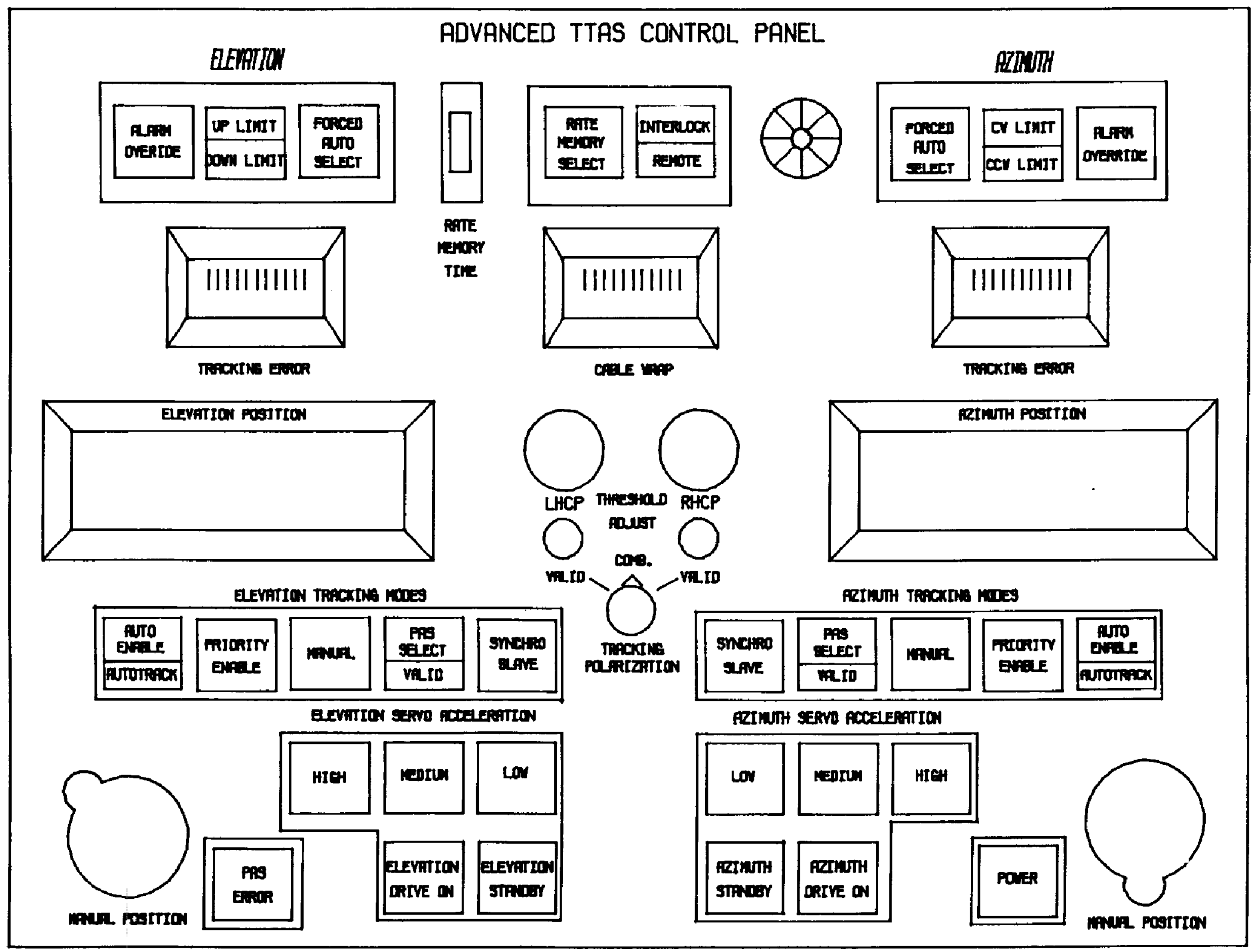

Figure 5. ACU Front Panel.