THE NEW GENERATION OF COMPACT, FLEXIBLE, ANTENNA CONTROLLERS

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ABSTRACT

TIW Systems has developed a modern, compact, modular, antenna controller (ACU) for telemetry, tracking, and communications antennas. The controller combines the functions of an antenna control unit, a position conversion/display chassis, and a polarization control unit. By using plug-in cards, a tracking receiver, autophasing control unit, tracking synthesizer, and other functions can be added. Depending on the requirements, the tracking receiver can be a simple wide-band steptrack receiver, or can be a full function phase-locked-loop (PLL) autotrack receiver. In the past, all this capability would have taken a large portion of an entire equipment rack.

The unit uses modern microprocessor technology for digitally controlling the position and rate of the antenna. Advanced tracking modes and remote control can be added by connecting an external computer (PTIC) to one of the ACU's serial ports. The PTIC also provides a user friendly operator interface through the use of high resolution color graphics and easy to understand menus.

KEY WORDS: ANTENNA CONTROL UNIT, ANTENNA CONTROLLER, TRACKING SYSTEMS

INTRODUCTION

In the past, telemetry, tracking, communications, and radio telescope antennas have required many chassis to do the positioning and tracking functions of the antenna. Depending on the exact system requirements, the following equipment has been required:

- An antenna control unit for controlling the operating mode, position, and rate of the antenna.

- A position conversion and display chassis for converting the antenna's position transducers to digital format.

- A polarization control unit to rotate (and display) the position of the polarizer in the microwave feed. This type of unit is used on antennas that receive linearly polarized RF signals.

- A tracking receiver for use in automatic tracking modes.

- An autophase control unit to maintain the correct phasing between tracking receiver channels.

- An RF synthesizer for selecting the tracking frequency.

With today's technology, it is possible to provide all the above functions (and more) in a single rack-mounted chassis. TIW's new antenna control unit is an example of the next generation of antenna controllers that have become available. This paper will describe some of the features of this new controller.

ANTENNA CONTROLLER

The TIW Antenna Controller (ACU) is a modern, modular, expandable unit based on the Motorola 68000 microprocessor. The ACU front panel, shown in Figure 1, uses "tactile feel" switches, audible keystrokes, and a menu-driven, alphanumeric display to provide a convenient operator interface. The unit is designed to allow limited manual operation of the antenna even if the microprocessor should fail.

The top three lines of the ACU's alphanumeric display show a wealth of information. These lines display the antenna's azimuth/elevation angles, commanded angles, signal level, linear polarization angle, error messages, and system parameters. The bottom line of the display labels the current use of the six, menu-driven function keys (F1-F6). A hard-wired Emergency Stop switch provides an interface to the antenna drive subsystem.

The ACU uses a custom motherboard with two busses to achieve a high degree of modularity, flexibility and expansion capability. One buss is the industry standard G-64/G-96 computer buss. The second buss (TIW designed) contains an addressable I/O channel and some user definable lines. The motherboard holds a wide variety of card types and sizes. The cards plug in from the top of the ACU and use high quality DIN socket connectors for maximum reliability. The basic unit contains the following:

- System microprocessor
- Three serial I/0 ports
- Self-test
- Front panel interface circuits
- EPROM, EEROM, and battery-backed RAM
- Station alarm
- Real time clock
- Power supplies

The following types of cards are available to meet the requirements of a particular application.

- Drive interface (DC, AC or DC/AC models)
- Step track receiver (wide-band AM detector)
- Step track receiver (narrow-band PLL)
- Two or three channel PLL autotrack receiver
- Pseudo-monopulse receiver and scan driver/decoder
- Frequency Synthesizer
- Autophase I/O
- Position Conversion and Display Interfaces:
  - Optical encoder interface (up to 24 bits)
  - Single speed synchro or resolver
  - Dual speed synchro or resolver
  - Dual speed optical encoders
- Optically isolated and relay I/O
- Single and differential TTL I/O
- Multi-axis subreflector control
- Standard "off-the-shelf" G-64 or G-96 cards
- Custom designed cards to meet specific user requirements

The ACU provides all the standard operating and tracking modes of the older generation units. These modes include: Standby, Manual Rate, Command Position, Scan, Steptrack, Autotrack, Memory Track, and others.

The ACU also implements the newer tracking modes such as smart steptrack. In this mode, the ACU is initially in steptrack mode while it gathers enough data to make orbital predictions. After a few hours, the ACU can predict the orbit of the target and can reduce the amount of active tracking required. The ACU can then move the antenna smoothly along the predicted path rather than do continuous stepping. This has the benefit of reducing the wear on the antenna's mechanical parts. Once the orbit is determined, active steptracking is only performed several times per day to update and refine the orbital model. After several days of tracking the ACU can predict the drift rate and drift acceleration of the satellite and can therefore increase the accuracy of the predictions. Smart steptrack has several thresholds that protect the system from discontinuities in the data. Discontinuities are typically caused by moving the antenna to another satellite or by satellite maneuvers. Whenever this occurs, the system will automatically return to active tracking and new data on the orbit will be taken.

The remaining portion of this paper will describe the features and technical specifications of some of the major features of the new antenna controller.

TRACKING RECEIVERS

Many antennas require automatic tracking of a satellite or other signal source. This requires some sort of tracking receiver depending on the type of automatic tracking desired. The new ACU supports all of the major automatic tracking modes in use today by plugging in the proper receiver cards.

Steptrack Receivers

Steptrack refers to systems with tracking ability based on the signal strength of the target to be tracked. These systems use a one-channel receiver to provide a DC output that is proportional to the received signal strength. A software algorithm then moves each of the two antenna axes (one at a time) to maximize the received signal level. The algorithm remembers the signal level before and after each step and then decides which way to move that axis during its next step.

Depending on the system requirements, the tracking receiver for steptrack mode can be one of several types. The two most commonly used ones are a simple, wide-bandwidth AM receiver and a narrow bandwidth PLL receiver. In either case, an AGC loop provides the necessary signal strength information to the software algorithm. The ACU will implement either type of receiver by plugging in the proper circuit card. The technical characteristics of the two types of steptrack receivers are shown in Table 1.

The PLL receiver has all the features associated with a sophisticated receiver including:

- Autosearch Tuning
- Adjustable Tracking Thresholds
- Selectable PLL Bandwidths
- Adjustable AGC Response Times
- Anti-sideband Locking
- Loop Open
- Loop Short
- Manual Open
- Status Outputs
- Linear AGC
- Manual Tuning
- Loop Stress Meter
- Tuning Frequency Meter
- Audible Beat Note
- Full Remote Control

Table 1. Steptrack Receiver Specifications

Description	Wide Bandwidth Receiver	Narrow Bandwidth PLL Receiver
Input Signal:	---	---
Center Frequency (MHZ)	70	70
Impedance (Ohms)	50	50
Level (dBm)	-30 to -70	-40 to -100
Tuning Range (kHz)	N/A	± 150 (linear range)
Linear Dynamic Range (dB)	40	60
AGC Linearity Over Dynamic Range (dB)	± 3 max	< ± 0.5 typ < ± 1.0 max
AGC Time Constant (ms)	300	3, 30, 300, 3000
Type of Receiver	Non-coherent AM	Coherent (PLL)
Bandwidth	240 kHz min (-3 dB) 1100 kHz max (-50 dB)	300 - 3000 Hz Selectable
Input VSWR	1.5:1	1.5:1
Noise Figure (dB)	12	14
Tracking Output	2.5 dB/volt	3.0 dB/volt

Autotrack Receivers

Autotrack refers to the various systems where the antenna's microwave feed provides azimuth and elevation error signals as well as a reference (sum) channel. After suitable processing, the azimuth and elevation error signals are used to drive the antenna to track the signal source. Autotrack systems are typically classified as one-, two-, or three-channel systems. They are named according to how many RF channels are used to bring the Az, El, and reference (sum) information to the tracking receiver. Three-channel systems (Az, El, and reference) bring all the RF information down to the receiver in parallel. Two-channel systems typically have the Az/El information combined vectorially into one signal. This combined signal must be split apart into its two orthogonal components by the receiver.

One-channel systems AM modulate the Az/El error information onto the reference signal. The TIW ACU can accommodate any of the autotrack systems by plugging in the proper receiver cards.

Two- And Three-Channel Autotrack Receivers - The two- and three-channel systems use one card for the reference channel and an additional card for each of the error channels. The specifications and features of the reference channel card are the same as the PLL steptrack card described earlier. The specifications for the error channel cards are given in Table II.

Table II. Error Channel Specifications
(Two- And Three-Channel Systems)

Description	Specification
Error Input Signals	---
Frequency (MHZ)	70.000
Maximum Input (dBm)	-50
Minimum Input	40 dB less than reference
Impedance (Ohms)	50
Error Output Regulation (dB)	< ± 1 max (over 60 dB range)
Error Output Drift	< ± 1% of max output over 24 hours
Error Output Bandwidth (Hz)	12

One-Channel Autotrack Receiver - The receiver card for the one-channel autotrack system is an AM detector with selectable IF bandwidths and AGC response times. The receiver has an input frequency of 70 MHZ and an AGC linearity of ±2 dB over a 60 dB dynamic range. The receiver includes the scan driver circuitry for AM modulating the Az/El error information onto the reference channel. The receiver also includes the circuitry for demodulating and separating the error information.

AUTOPHASING CONTROL

In multiple-channel autotrack systems, the phase of the error channel(s) contains information on the direction of the antenna to the satellite. This means the relative phase between the reference (sum) and each error channel must be adjustable. This is typically done by placing a phase shifter in each of the error channels. When the tracking frequency, polarization, or physical path length changes, each error channel must be re-phased. Depending on the system requirements, automatic phasing may be required. For these systems, the ACU is supplied with an autophase I/O card and autophasing software. This allows the ACU to read the status of the physical configuration, polarization, and other information needed for proper phasing of the receiver. The ACU software will then keep the phase shifters tuned to the right setting. The software provides both manual and automatic modes for determining the correct phase setting.

TRACKING SYNTHESIZER

When many frequencies are used for tracking, it becomes cost effective to use a synthesizer to control the local oscillator of the tracking downconverter. In the past, this function required an expensive, rack-mounted chassis. The TIW ACU has a plug-in synthesizer card to perform this function. The synthesizer card drives an agile source located in the tracking downconverter. In normal operation, the tracking frequency is set using the keypad on the ACU front panel or through the ACU's remote interface. For test purposes, the synthesizer can be controlled manually with a series of DIP switches. The ACU will automatically re-phase the tracking receiver whenever the synthesizer frequency changes. The specifications for the synthesizer are given in Table III.

Table III. Tracking Synthesizer Specifications

Description	Specification
Frequency Band (MHZ)	88.500 - 120.000
Frequency Step Size (Hz)	0.012
Frequency Stability	$\pm 5 \times 10^{-8}$
SSB Phase Noise (dBc/Hz)	-100 at 100 Hz offset -110 at 1.0 KHz offset -120 at 10.0 KHz offset - 130 at $\geq$100 KHz offset
Spurious (dBc)	-55 minimum
Output Level (dBm)	(Adjustable) 0 to +10
Harmonics (dBc)	-35

REMOTE OPERATION

For remote operation, the ACU is connected to an external computer via a serial interface. Full control and status of all the various controller functions can be accessed over the interface. A hardware/software package (PTIC) is available for those users who wish to expand the remote capabilities of the ACU. The PTIC adds several advanced tracking modes and provides a color-graphic, menu-driven operator interface. Figure 2 shows one of the screen layouts for PTIC package. The PTIC software adds the following modes of operation: computer track, NORAD track, INTELSAT track, star track, and augmented steptrack. These modes are described below.

Computer Track

This mode allows an external computer to load time tagged Az/El data into the PTIC's memory. After the data is loaded, the ACU will position the antenna according to the time/Az/El data it receives from the PTIC. The ACU can add azimuth, elevation, and time offsets to the computer track trajectory.

NORAD And INTELSAT Track Modes

These tracking modes allow the user to send NORAD or INTELSAT element sets to the PTIC. The ACU will then command the appropriate Az/El angles at the right time to track the object. The ACU can add azimuth, elevation, and time offsets to the calculated trajectory during the track. The PTIC supports four NORAD orbital models: SGP, SGP4, SDP4, and SDP8.

Star Track

The star track mode allows the user to select and track one of several stellar sources. This mode is useful for making G/T measurements of the antenna's performance. Azimuth, elevation, and time offsets can be added during the track.

Augmented Steptrack Mode

This mode superimposes the standard steptrack mode on top of a computer track, NORAD track, or INTELSAT track. This allows the ACU to track out any Az,El, or time offsets that may be present in the computer generated trajectories. Augmented steptrack allows the ACU to track relatively fast moving targets with an inexpensive steptracking system. In many instances, this mode may make it possible to avoid the extra cost associated with a monopulse autotracking system.

CONCLUSION

This paper described some of the features of TIW's new antenna controller. The new controller integrates into one chassis the functions of an antenna control unit, position display unit, polarization control unit, tracking receiver, autophase control unit, and a frequency synthesizer. More functions can be added through the use of custom-designed, plug-in cards. Advanced tracking modes and a color-graphics operator interface can be added via one of the ACU's serial ports.

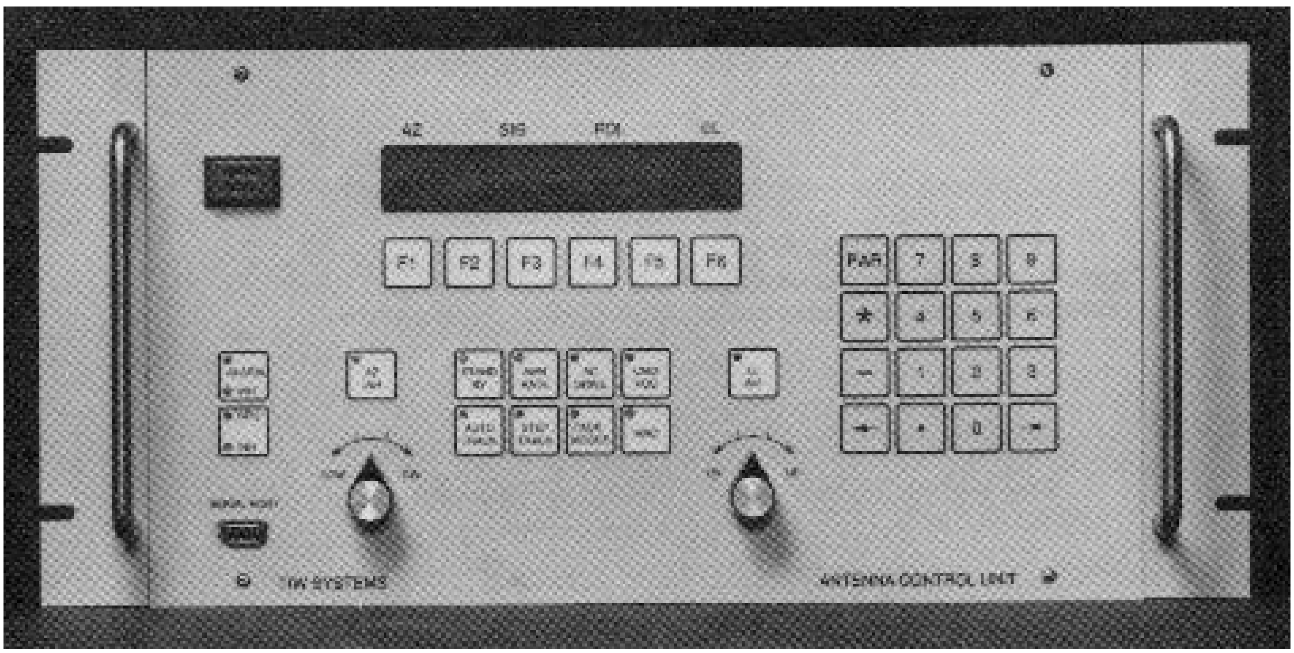

Figure 1. Antenna Controller

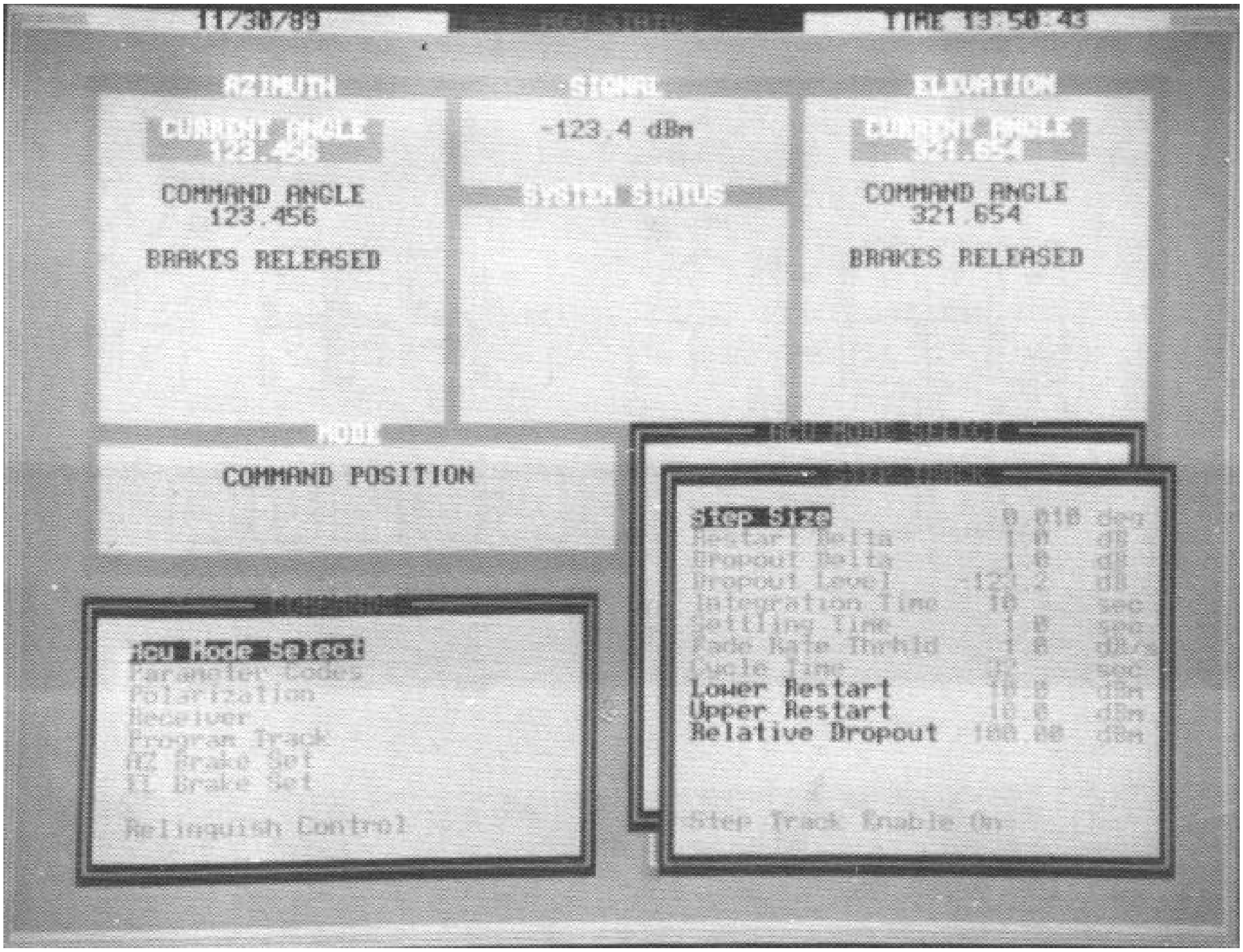

Figure 2. Screen Layout