A New Approach to High Reliability UHF Controllers

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Many available UHF antenna positioners lack reliability for high-intensity commercial use. Similarly, many UHF antenna controllers lack appropriate interfaces for remote and automated control.

We present a number of ways to simplify UHF ground station design and improve reliability. We also describe an improved antenna controller we have designed, with Ethernet connectivity, human- and machine-friendly interfaces, detailed metrics for fault diagnosis, and an improved control algorithm designed to minimise gearbox stresses and improve pointing accuracy.

Coaxial Cable Twists

A common fault on UHF antennas over time is the failure of coaxial cables at the cable twists, where they pass the elevation and azimuth motors. Thinner cables are more flexible and less prone to such failures than thicker cables, but they also have higher attenuation, so they should not be used before the LNA.

Make It Twist

Mounting the LNA on the antenna boom—instead of in the pedestal—allows flexible but more lossy coaxial cable to be used for the cable twists without degrading the system noise figure.

Antenna Lifespan and Maintenance

Frequent satellite passes cause wear on the moving parts of an antenna system. Compounding this, UHF antenna controllers often use "bang-bang" or "on/off" control output to the motor, resulting in large and frequent fluctuations in acceleration. These fluctuations excite significant vibrations in the antenna system, accelerating cyclic wear and leading to increased maintenance and downtime.

Smooth Ride

A predictive control algorithm with variable speed output has been developed. This algorithm combines interpolation and extrapolation of commands to maintain smooth and continuous speed control, minimising acceleration and jerk on the system, reducing cyclic wear.

Azimuth Range

Many satellite passes travel in an approximately north-south or south-north direction, crossing either the 360°/0° or ±180° azimuth boundary, which is problematic for 360° azimuth range south- or north-centred positioners respectively: when the spacecraft passes across the respective boundary, the antenna must rotate 360° in the opposite direction to "unwrap" itself before continuing the pass.

A Flipping Good Time

To eliminate this backtracking, a 180° range elevation axis can be used in conjunction with a 360° range east-centred azimuth axis. Passes crossing the:

- Eastern axis use elevations angles 0° to 90°
- Western axis use mirrored elevation angles (180° to 90°) and use 180° offset azimuth angles.

Because the elevation inversion is a simple linear transformation—for both the elevation and azimuth axes—the controller can simply be set to 'standard' mode or 'flipped' mode pre-pass, removing the algebra from the higher-level scheduling service.

Additionally, the flipped mode can be used for double-verifying the antenna azimuth and elevation calibration against fixed targets, reducing calibration inaccuracies due to squint or when the positioner is mounted on unlevel surfaces.

Position Encoding

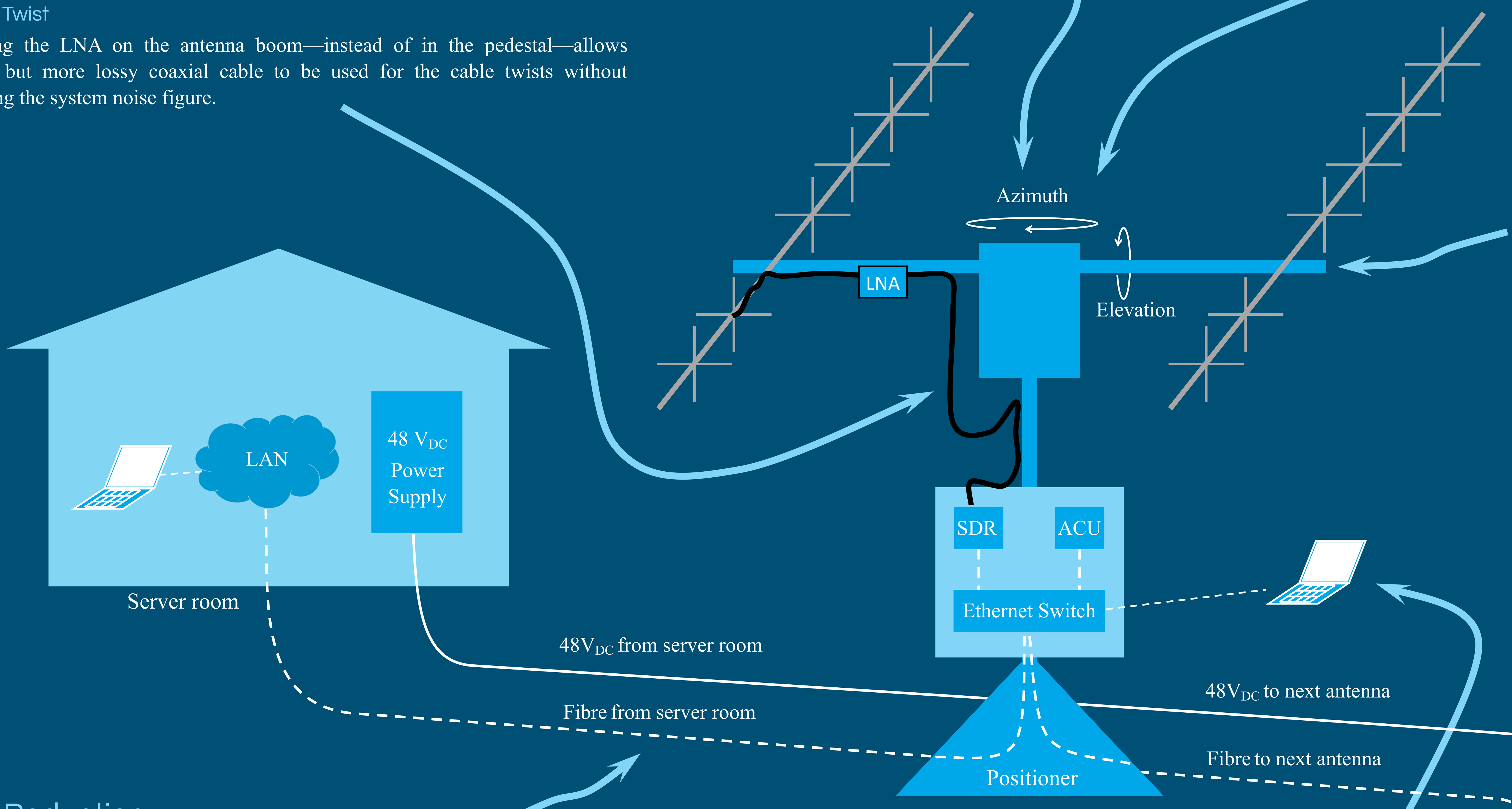
Two position encoding methods commonly used in UHF antenna positioning systems are

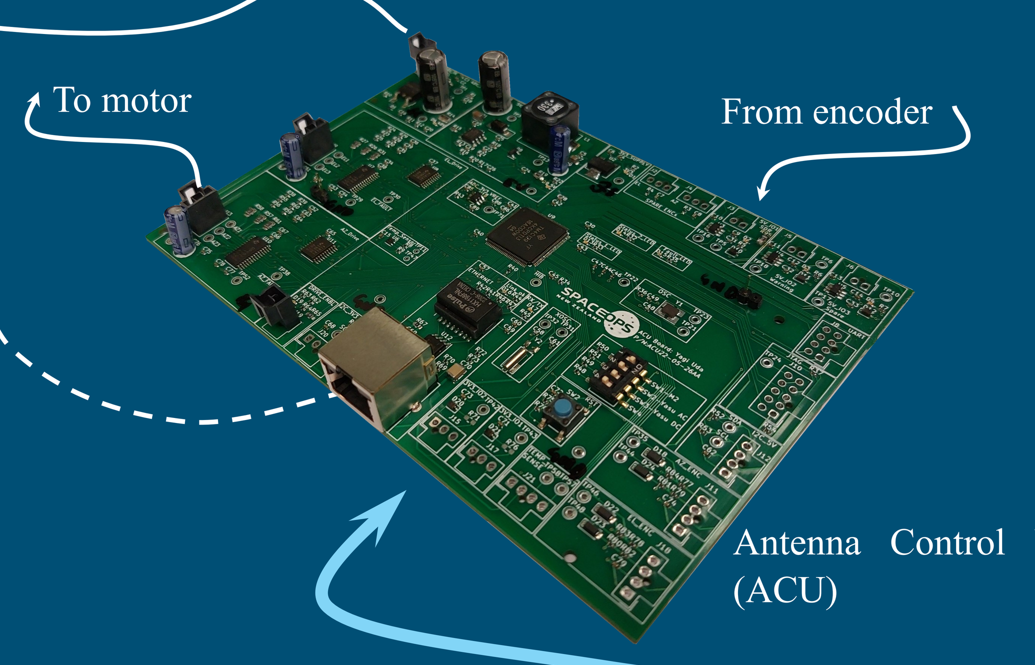
1. Potentiometer-based analogue position encoders
2. Single channel incremental digital position encoders

While potentiometer encoders provide an absolute position measurement, they are often noisy. Conversely, incremental encoders are less noisy, but provide a relative position measurement. Additionally, because the incremental encoders are single-channel, they rely on the motors being actively driven to determine the direction of rotation. When the motors are deenergised, encoder pulses are ignored, allowing the positioner to drift out of calibration over a comparatively short time-span.

Staying on Track

Our antenna controller includes provision for both analogue and digital position encoding systems. This allows the controller to be used as a drop-in replacement for many existing systems. Alternatively, retrofitting an existing system with a digital quadrature encoder in addition to our antenna controller will increase the accuracy and precision of the system, reduce noise in the position measurements, and reduce recalibration requirements.





Cost Reduction

Traditional UHF ground station design requires at least one coaxial cable to be run from a server room out to each antenna. However, coaxial cable is and associated ducting is expensive, so minimising the total length used is desirable.

Additionally, UHF antenna controllers are typically mounted inside the server room, with multi-core cable run to the antenna for motor control and feedback. Cumulatively, the multi-core and coaxial cables result in substantial ducting and cabling costs for each antenna.

Cheaper than Coax

Mounting a Software-Defined Radio (SDR) in the antenna pedestal eliminates the need for coaxial cables back to the server room. The coaxial connection can instead be replaced by a cheaper Cat 6 or fibre optic cable—which the SDR's IQ output an be digitally streamed over.

No More Multi-Core

Similarly, mounting the antenna controller at the antenna pedestal replaces the multi-core cables with a simple network connection and a 48 V_{DC} power supply bus.

Bringing it all Together

Mounting a network switch in the pedestal allows the antenna controller and SDR to share the same network connection. Furthermore, the antenna controller provides a 5 V_{DC} power output for the SDR. Consequently, only a high-speed network connection and a simple 48 V_{DC} bus are required to support the antenna controller, the rotator, and the SDR, minimising cabling requirements.

Scaling Up

For ground stations where multiple UHF antennas are installed, a series of antennas can be daisy-chained together on a single run of Cat 6 or optic fibre, and a single 48 V_{DC} bus, further minimising ducting and cabling.

Antenna Interface

Many UHF antenna controllers provide a serial interface for external control and monitoring. While serial connections are reliable, they make it difficult to send commands to the antenna controller over long distances, or to support simultaneous users operating and monitoring the antenna. To support this, a separate "Ethernet-to-serial" interface is often required, which adds development time and complexity to the system.

UHF antenna controllers also tend to have limited feedback metrics, often providing only the antenna position and the limit switch states. This lack of data can obfuscate faults and delay fault detection, slowing down troubleshooting and maintenance.

Staying Connected

We have developed an antenna controller with a standard TCP/IP Ethernet interface, enabling commands to be sent directly to the controller over long distances and allowing multiple simultaneous (remote) connections. Our antenna controller provides a simple, human-readable JSON API for control and monitoring. This API can be accessed over the TCP/IP connection via two different protocols:

1. Raw TCP/IP socket connection, for connection to automated systems via JSON
2. HTTP connection, for field access via a user friendly web app or automation using JSON structured POST requests.

Metrics to the Rescue

Building on knowledge gained from our previous 3.7m S-/X-Band ACU, our new antenna controller offers detailed metrics—such as motor current and voltage, temperature, and humidity. These metrics help detect and diagnose issues quickly, or even predict them before they occur, minimising down-time. The elevation motor torque metric can be especially useful during installation to accurately balance the yagi antenna on the elevation axis: a well balanced axis helps ensure positioner longevity.

Calibration

A new calibration methodology has been developed using software-defined, editable position offsets to allow quick and easy calibration of the antenna via the controller's web interface. Two types of position offset are defined:

1. The 'calibration offset' corrects for a constant error in the measured encoder position. The value of this offset is stored in non-volatile memory.
2. The 'user offset' may be used to temporarily offset the antenna's pointing direction. This parameter is always initialised to 0 °.

The calibration offset is intended for long-term calibration of the antenna. It can be easily set by specifying the current physical position of the antenna, or its value can be set manually.

By contrast, the user offset is intended for applying temporary, possibly time-varying biases to the antenna's pointing direction. This functionality is useful in many scenarios—such as performing a conical-scan for a satellite based off an approximate orbital track, or fine-tuning a new calibration offset value without overwriting the existing calibration.

Automation to the Limit

Once the antenna has been calibrated for the first time, our antenna controller stores the positions of the antenna hard-limits to non-volatile memory. The controller can then perform subsequent calibrations automatically, by moving the antenna onto a hard-limit and updating the calibration offset based on the hard-limit's known position.

Further Information:

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