Peter Shield et al.: A New Lower Cost 12m Full Motion Antenna, IVS 2006 General Meeting Proceedings, p.77–82
http://ivscc.gsfc.nasa.gov/publications/gm2006/shield

A New Lower Cost 12m Full Motion Antenna

Peter Shield, Mark Godwin

InterTronic Solutions, Patriot Antenna Systems Inc.
Contact author: Peter Shield, e-mail: `pshield@intertronicsolutions.com`

Abstract

A new lower cost 12m Ka band antenna and pedestal together with a novel high accuracy control system has been designed and delivered to NASA JPL for the DSN array. This new antenna was designed and manufactured by Patriot Antenna Systems to suit their higher volume manufacturing techniques and has taken advantage of the latest mechanical structures and control loop components available to achieve cost targets for larger Ka band antennas never seen before. The surface accuracy of this new design is 0.012 inches RMS including temperature and wind effects and its control system is capable of less than 0.005 degree RMS absolute pointing accuracy (spatial coordinates) using fast response position and speed control loops. The control system uses only economical, standard commercial modules and provides a wide speed range - repositioning to anywhere on sky within 2 minutes and with tracking at speeds down to much less than 1 millidegree/sec. Corrections for axes misalignments are built into the controller and a choice of interfaces allows antennas in an array to be nodes on a LAN such that a controlling computer can broadcast common instructions to all antennas. Each antenna can store track data to execute at scheduled times and has facilities for initial pointing calibration and calibration monitoring. This antenna is suitable for deep space communications, radio astronomy, conventional GEO and even LEO satellite communications. Several options are available for the drive system mechanics including conventional gear drives in both axes as well as more economical precision jack screw elevation drives.

1. Introduction to Patriot

Patriot has a 300,000 sq. ft. factory in Albion, Michigan, USA. Patriot's advanced mechanical design & analysis tools and capabilities include the

- principal design tools
  - AutoCAD and
  - Solid Works.
- Mechanical analysis is available for
  - wind load and forces software (MIT Lincoln Lab Report 71G-5),
  - Von Mises stress/deflection calculations,
  - thermal effects,
  - natural resonant frequency, and
  - FEA using Ansys.
- Laser photogrammetry rounds out the mechanical design and analysis tools.

Patriot is also very well equipped with all the latest high volume antenna manufacturing tools needed. These include

- a new large Taurus mill for tooling,
- a new laser cutter and welder,
- CNC mills and CNC lathes,
- 22 presses ranging from 50–1250 tons,
- press brakes, shears, and saws

providing complete manufacturing capabilities.

Figure 1. Patriot facilities at Albion, Michigan, USA.

Powder coating is used as a finish treatment instead of regular paint, as powder is much more durable and environmentally friendly. Patriot has two powder coating lines together with huge warehouses. Proven stretch-formed antenna panels are used that provide superior, accurate surfaces and repeatability; in-house tooling and machinery is used to stretch the panels.

2. 12m Cassegrain Antenna Key Specifications

The key specifications and features of the 12m Cassegrain antenna are:

- Surface accuracy: 0.3 mm (0.012 inches) overall RMS. Contributing causes: 0.008″ manufacturing, 0.005″ wind, 0.005″ temperature, and 0.005″ gravity. Easily suitable for use at up to 32 GHz.
- Dual shaped, F/D 0.375.
- Pointing accuracy: 0.005°.
- No on site panel alignments required.
- Factory assembled mount reduces installation time.
- Designed for lower cost volume manufacture in a wide range of sizes and configurations.
- Operating temperature range: -15°C to +55°C.

- Specifications apply in winds of up to 35 mph.
- 100 mph survival in stow.
- Antenna mounts on a typical 24-ft square, 4-ft thick concrete pad.
- Included with antenna are a template and bolts for setting into the pad.
- $+5^\circ$ to 90° elevation travel.
- $\pm 270^\circ$ azimuth travel.
- Antenna weight: 34,500 lbs.
- Entire antenna ships on two trucks or in two standard 40 ft shipping containers.

Figure 2. 12 meter antenna installed at JPL.

3. 12m Antenna Detailed Mechanical Features

The main antenna components are the pedestal (made of welded steel), the turning head assembly, and the reflector and hub (made of aluminum).

3.1. Turning Head

The turning head assembly is attached to the azimuth bearing and provides the azimuth and elevation motion of the antenna system. The base plate of the turning head is machined concurrently for the bearing and gearbox interfaces. This approach provides very accurate meshing of the drive pinions to the azimuth gear with minimal field alignment.

Figure 3. Constructing the 12m antenna.

3.2. Azimuth Drive

The azimuth drive is a typical dual pinion anti-backlash design which includes integral pinions, fail-safe brakes, drive motors and gearboxes. The azimuth drive components are bolted together into an assembly that bolts vertically onto the turning head.

3.3. Elevation Drive

The elevation drive assembly consists of an oversized 100 ton ball screw actuator, gearbox, motor, brake and encoder bolted together in a horizontal assembly. Due to the geometry of the antenna the elevation actuator is always loaded in compression under operational conditions. This eliminates the effects of backlash in the system.

3.4. Reflector Assembly

The reflector assembly consists of the hub, radial trusses, bracing, panels, rear closeouts, subreflector and subreflector supports. The hub is a drum structure with machined interfaces for the pedestal and radial ribs. The front face of the hub also is the interface plane for the feed system and support structure. The ribs are attached to the hub at machined interface points and supported by back support struts and bracing that rigidly tie the reflector system together. There are 24 main ribs with 24 intermediate ribs to help support the outer tier of panels. The subreflector struts are pin-connected to the reflector and arranged in a quad configuration and provide mounting and adjustment for the lightweight composite subreflector. The rear closeouts provide added stiffness and means of thermal protection for the structure. This reflector system has been chosen for its rigidity, ease of manufacture and ease of installation. The design is cost effective and easily transported. Installation time is minimized by the use of highly accurate parts and minimal alignment requirements.

4. Maintenance Features

The maintenance features can be summarized as follows:

- Azimuth motors and gearboxes are changeable without major work.
- The elevation jack is replaceable without cranes etc.
- In-pedestal electronics permits easy access to the drives.
- Only simple routine maintenance procedures are required.

5. 12m Antenna Detailed Electrical Features

The philosophy adopted in the design of the pointing control system was to use COTS equipment and to minimize or even eliminate ad hoc equipment. This approach has resulted in a configuration in which the position control loops are closed within inverter drives, rather than in an external computer as is often the case in antenna pointing systems

The inverters used supply variable frequency, three phase power to the motors to control speed. Motor speed feedback is supplied by 4096 line/revolution incremental encoders. On both axes a feed-forward speed control loop and a precision position loop are used. A 4 msec update rate is used for the position control loop.

Brushless AC servo motors are used as they provide the high torque required for accurate servo position control. The motors also include brakes and speed encoders. On the azimuth axis two 2.5-kWatt motors and gearboxes are used in a torque biased configuration. In the elevation axis one 3.25-kWatt motor is used.

A control equipment cabinet is used for the drive electronics. This is housed in the pedestal eliminating the need for a separate building.

The antenna can be supplied with various software interfaces that enable the complete elimination of a separate ACU.

Go-to commands, program track and several coordinate systems can be accommodated. Exceptionally versatile and accurate motion is accomplished with the control system. A very wide speed control range can be achieved with no overshoot when arriving on target.

26 bit Heidenhain optical absolute encoders are used that can provide a resolution of 0.0000054 degrees. The smallest increment actually used is 0.0001 degrees.

Antenna repositioning to anywhere on the sky within 2 minutes and tracking at speeds down to much less than 1 millidegree/sec are achieved. Corrections for axes misalignments are built into the controller and a choice of interfaces allows antennas in an array to be nodes on a LAN such that a controlling computer can broadcast common instructions to all antennas. Each antenna can store track data to execute at scheduled times and has facilities for initial pointing calibration and calibration monitoring

6. 12m Antenna Measured Performance

The maximum slew and scan rates are:

- up to 3–6 deg/sec in azimuth.
- up to 0.7–3 deg/sec in elevation.
- Speed range changes can be accomplished by using modified gearbox ratios.
- Accurate pointing down into the 1–2 millidegree range has been reported from measurements made so far.

7. 12m Antenna Applications and Configurations

The 12m antenna supports the follwing applications and configurations:

- fixed pointing;
- limited motion;
- full motion: ±270 degrees;
- GEO communications;
- LEO communications;
- DSN tracking;
- TT&C applications;
- radio astronomy;
- 2-port or 4-port feed configurations;
- high wind and other custom designs;
- CP/LP switchable, monopulse feeds;
- antenna drive and control system pptions;
- 6 to 18 meter for S, C, Ku, Ka, and X-band;
- 3rd tilt axis for keyhole elimination.

Contact Information

For further details please contact:

Peter Shield
InterTronic Solutions Inc
452 Aime-Vincent
Vaudreuil-Dorion
Quebec, Canada, J7V 5V5
Tel: +1-450-424-5666
Fax: +1-450-424-6611
Email: pshield@intertronicsolutions.com