Modernizing the Antenna Control System of USNA’s 12m Satellite Dish

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Overview

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12m Dish Background

- Originally part of the NASA satellite tracking network at NASA Goddard Space Flight Center [1]
- Installed at USNA in 1989
- Current control system: PC104/PC microprocessor controller
- Used for:
  - Satellite communications
  - TV uplinks to the space shuttle
  - Live TV feeds from Russian geostationary satellites for Russian language courses

Figure 1. 12m dish at Hospital Point
Purpose and Scope

“The US Naval Academy would like to upgrade the 12 meter dish to operational status using a simple Arduino type microcontroller so that we have full control over the dish and have the source code for long term maintenance…” [2]

Figure 2. Depiction of transition from old PC-104 controller to new Arduino controller [2].
Requirements

1. Design a control scheme based upon Arduino Uno microprocessors

2. Create and test a scale model for design validation
   a. Manual control
   b. Autonomous control via SATPC32

3. Assess current 12m dish capabilities and faults

4. Implement control scheme for 12m dish
   a. Manual control
   b. Autonomous control via SATPC32
Concept of Operations

1. Scale Model Dish Controller
2. Hospital Point 12m Dish Controller
3. Rickover Ground Station 12m Dish Remote Controller*

Total of 6 Arduino Uno microprocessors.

Figure 3. Overview of proposed solution. Includes two Arduino Uno microprocessors at each location.
Scale Model for Controller Development

**Purpose:** To test and refine critical controller software for future implementation on the 12m Dish.

2 Major Components:
- Scale Model Antenna Dish
- Dish Status Simulator Box

Figure 4. Scale Model Antenna Dish (left) and Dish Status Simulator Box (right)
Scale Model: Mechanical Design

Components:

- Dual gear-reduced DC motors
- US Digital S1 optical shaft encoders
- Metal parabolic dish
- Metal cylindrical dish base
- Custom-made motor housing
- Wood base

Figure 5. Final draft of 12m scale model
Scale Model: Motor Controller Software

Overall Control Method:
Pulse-Width Modulation (PWM) using an H-Bridge chip to change motor direction.

4 modes:
1. Manual Control
2. Zeroing Azimuth/Elevation
3. Demo
4. SATPC32 Tracking

Figure 6. PWM control uses changing duty cycles to control the applied voltage

Figure 7. SATPC32 tracking software.
Scale Model: Motor Controller Hardware

Components:
- Arduino Uno microprocessor
- LCD Display
- L293D H-bridge

- Analog control joystick
- Serial connector for SATPC32
- Mode Switches

Figure 8. Scale Model Controller Hardware.
Scale Model: Demonstration
Scale Model: Dish Status Simulator Box

- White switches/LEDs simulate command inputs.
- Black switches simulate dish system status inputs.
- Inputs are processed using a voltage divider in order to minimize the number of pins used.

Figure 9. Dish status simulator box. This case shows that the klaxon & pump are on, X & Y brakes are off, and the hydraulic pump system is operating nominally.
Scale Model: Testing and Results

- Scale Model Antenna Dish has been successfully tested in all four control modes
  - Successfully operates off of 5 V
  - Display operates as designed, showing the dish’s current azimuth and elevation
  - Zeroing scheme operates as designed
  - Exhibited sustained, autonomous tracking of satellites using SATPC32 software

- Dish Status Simulator Box has been successfully tested
  - All combinations of command/status inputs have been tested
  - Correct error messages are shown when improper combinations are entered
12m Dish Controller Implementation

**Purpose:** Implement scale model solution for 12m dish operation

1 Major Component: Arduino Control Panel

- **Includes:**
  - Motor controller Arduino Uno
  - Status processing Arduino Uno
  - Arduino PCB Shield
  - DB-25 status connector
  - Manual control joystick
  - Power supply
  - LED indicators

![12m Dish Arduino Control Panel](image)

*Figure 10. 12m Dish Arduino Control Panel. User facing side (top) and flipped back side (bottom).*
12m Dish Controller: Control Panel (motor control side)

Figure 11. 12m Dish Arduino Control Panel (motor control side). User side (left), back side (right).
12m Dish Controller: Control Panel (status processing side)

- LCD Display
- Arduino Uno
- Command Input Switches
12m Dish Controller: Current Status and Testing

● **12m Dish Status**
  ○ Y-axis shaft encoder not responding
  ○ X-axis interlock broken, restricting dish rotation along the X-axis
  ○ Hydraulic pump system operational
  ○ Power supply functional

● **12m Controller Testing**
  ○ Control panel undergoing in-lab testing
  ○ Joystick voltage calibration for manual control
  ○ DB-25 connection/12m dish status processing tests
  ○ Autonomous, SATPC32 control currently limited with the faulty Y-axis encoder and X-axis interlock
Conclusion

Requirements Revisited:

1. Design a control scheme based upon Arduino microprocessors ✓

2. Create and test a scale model for design validation
   a. Manual control ✓ ✓
   b. Autonomous control via SATPC32 ✓ ✓

3. Assess current 12m dish capabilities and faults ✓

4. Implement control scheme for 12m dish
   a. Manual control ✗
   b. Autonomous control via SATPC32 ✗
Future Work and Lessons Learned

Future Work:

- Repairing faulty 12m dish hardware (Y-axis encoder, X-axis interlock)
- Testing autonomous, SATPC32-based tracking on 12m dish
- Implementing remote control system in Rickover ground station after it is reopened

Lessons Learned:

- Difficulties arise when working with old, previously unused hardware.
- Scale model testing is highly useful for complex, large-scale projects
- It is important to pursue the goals that are feasible given the current situation regarding hardware issues.
References
