Development of a Precision Model Positioning System for a Multi-Use Electromagnetic Test Facility at NASA Langley Research Center

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***Abstract*— this paper describes the mechanical design, control instrumentation and software for a precision model positioning system developed for use in the Experimental Test Range (ETR) electromagnetic test facility at NASA Langley Research Center.**

I. Introduction

ADC has a contract to design, build, and install major components for an updated indoor antenna characterization and scattering measurement range at NASA Langley Research Center. State-of-the-art electromagnetic systems are driving a demand to increase the precision and repeatability of electromagnetic test ranges. Sophisticated motion control systems can help meet these demands by providing electromagnetic test engineers with a level of positioning fidelity and testing speed not possible with previous generation technology. The positioning system, shown in Figure 1, was designed for the Experimental Test Range at NASA Langley Research Center. It consists of a rail positioning system and four rail positioning carriages: an antenna measurement positioner, scattering and RCS measurement pylon, an azimuth rotator to support foam columns, and an electric personnel lift for test article access. A switching station allows for rail positioning carriages to be quickly moved on and off of the rail system. Within the test chamber there is also a string reel positioning system capable of positioning test articles within a 40’ x 40’ x 25’ volume.

ADC provides devices, integrated systems and a broad array of high-precision components and instruments to commercial, academic and government agencies worldwide [1].

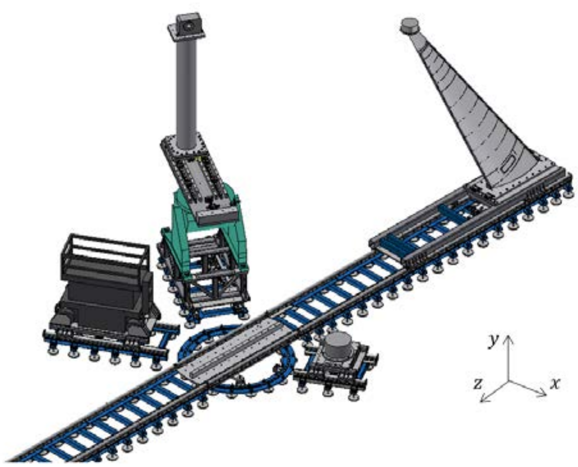

Figure 1. Experimental Test Range.

II. Rail System

The ETR rail system begins in the model prep area of the facility and ends 10’ past the center of the test chamber. Total travel from the center of the switching station to the center of the chamber test area is about 75’. A laser position encoder monitors position of the carriages. Accuracy of the encoder is 0.05” within the +/- 10’ of the chamber test area. A rack and pinion drives the carriages along the rail system. Rails mount to steel weldments that are supported with 8” diameter feet. Capacity of the rail system is 7,300 lbs.

III. Switching Station

A key feature of the rail system is the switching station. This allows for seamless interchange of positioning components onto and off of the rail system. Using the switching station, carriages are able to move independently. This also provides a place to dock positioning components when they are not in use. The switching station is rotated manually and indexed to align to three different positions to access all of the carriages. Figure 2 shows the transfer of the antenna positioner onto the switching station. Custom designed components are used to improve transfer and keep the rack and pinion system drive continuously engaged.

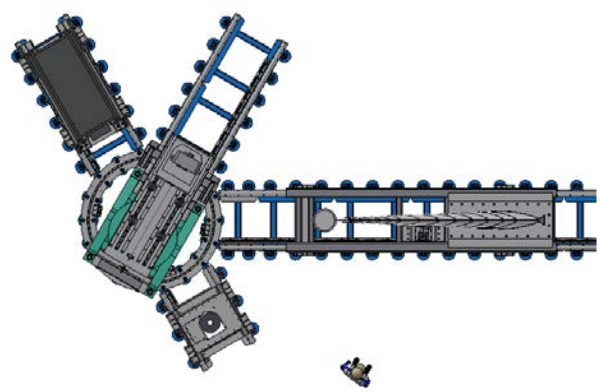

Figure 2. Experimental Test Range Switching Station.

IV. Antenna Positioner

The antenna positioner is a major component of the ETR. Mounted directly to the carriage is a Scientific Atlanta Az/El Positioner. On top of the Az/El Positioner is a manual offset slide with 4’ of travel from the center of the Azimuth rotation axis. Mounted to the slide is a large aluminum mast that supports an MI technologies roll positioner. The roll positioner has a 1,000 lb load capacity with 1,000 ft-lbs moment rating. These components are summarized in Table I below. With these components, antenna patterns can be measured from test articles by rotating about the azimuth and elevation axes. Part of this design was based on previous work done by ADC for LANL [2].

TABLE I. SUMMARY OF ANTENNA POSITIONER COMPONENTS.

Item	Description
Az/El Positioner	Scientific Atlanta Model Number: Prod Order #9371, Ass'y # 41385
Slide Assembly	4' Travel from Rotator Face to Vertical Axis of Rotation
Roll Axis Head	MI-56160D Positioner

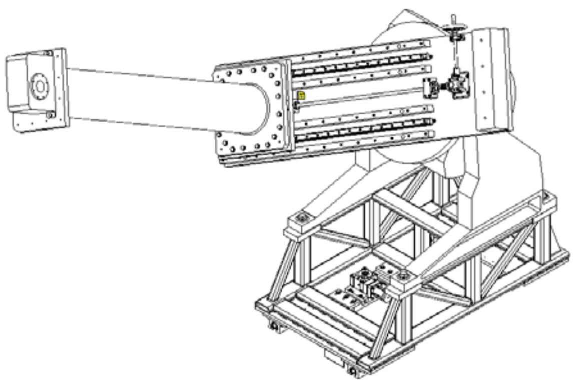

Figure 3. Antenna positioner rail positioning component.

V. RCS PYLON

The radar cross section (RCS) pylon is a 4:1 ratio ogive shape and has a 3,000 lb load capacity. This pylon, shown in Figure 4, was designed for a model height of 18’ relative to the facility floor and is able to support up to 3,000 lbs with a safety factor of 3.

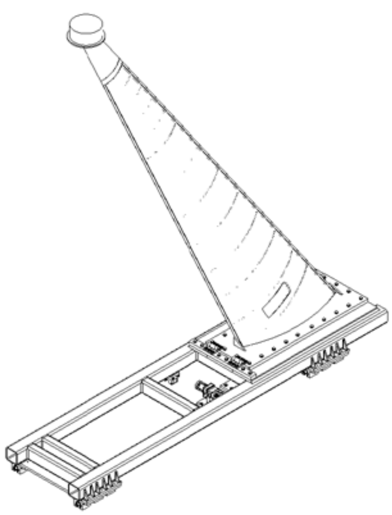

Figure 4. Pylon RPSC positioner.

The pylon is designed to operate with a spline driven tip or a pitch rotator tip that has an integrated drive system. For spline drive operation, a drive built into the pylon couples to a drive shaft. The drive shaft extends to the top of the pylon where it interfaces with the tip. The spline drive can be easily removed from the pylon for mounting and operation of the self-contained pitch tip.

ADC performed extensive FEA in order to develop and optimize the pylon structure. The pylon is manufactured from ¼” aluminum skin with internal ribbing for structural stability. Strength of the structure comes from the aluminum skin itself. Through FEA we were able to optimize the location of internal ribs and welds connecting the ribs to the skin. Figure 5 shows FEA stress results that estimate a maximum von Mises stress of 4.124 ksi at the base of the structure. Limits for structural loading are based on specifications from the Aluminum Association’s *Aluminum Construction Manual*.

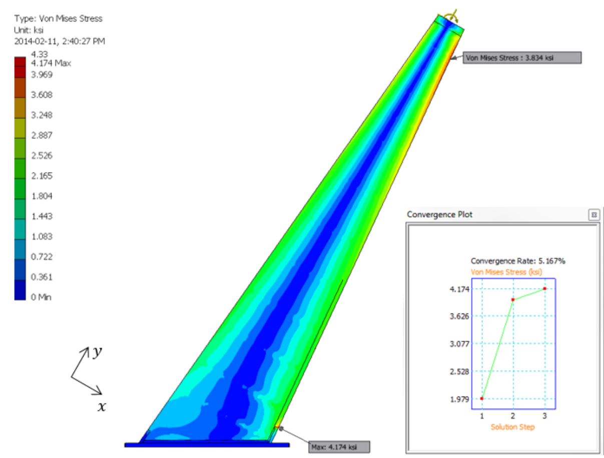

Figure 5. FEA analysis of the pylon under maximum load.

VI. AZIMUTH POSITIONER

Figure 6 shows the azimuth rotator positioning carriage. This component is a carriage for mounting azimuth rotators. Mounting features on top of the carriage offer compatibility with several different sizes. Foam columns will be mounted on top of the rotators so that the azimuth positioner carriage can be used with lighter test articles or to rotate objects connected to the string reel positioner.

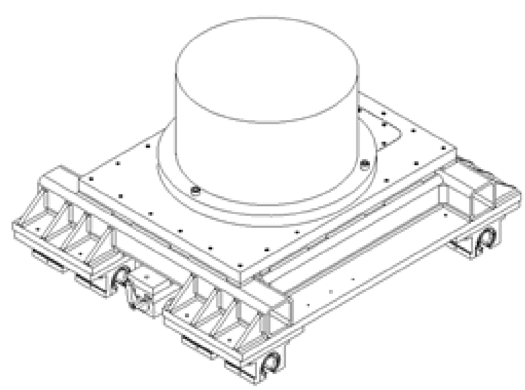

Figure 6. Azimuth rotator RPSC positioner.

VII. MANLIFT POSITIONER

The manlift rail positioning component, shown in Figure 7, is used for access to test articles and equipment on the range. An electric manlift sits on the platform of the carriage. Wheel stops prevent motion of the manlift. The rail system beneath the positioner are wide enough that the manlift stability is not compromised.

VIII. STRING POSITIONING SYSTEM

A string reel system has a 40' x 40' x 25' tall cube of operation and can position objects weighing up to 1,500 lbs. Positional accuracy of the string reel system is 1". Spectra cord is used for the string reel system because of high strength, size,

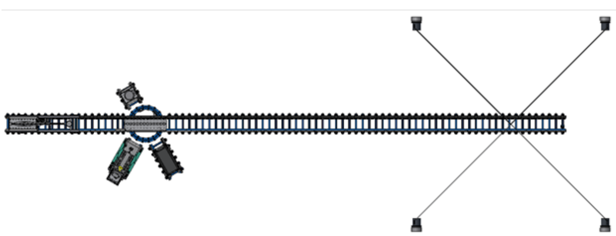

Figure 7. Top view of the experimental test range. The string reel positioning system is shown on the right.

and low creep properties. Load cells monitor the load on individual strings and shut down the system in the case of accidental overload. To get full range of positioning within the 40' square area, 4 strings are used. Each string is positioned with an Orbit F/R string reel. Rotary encoders on the string reel provide feedback to the controller which monitor the calculated position of the test article. Figure 8 shows a schematic view of the string reel system. The origin of the positioner is located on the floor plane and centered on the 40' x 40' area.

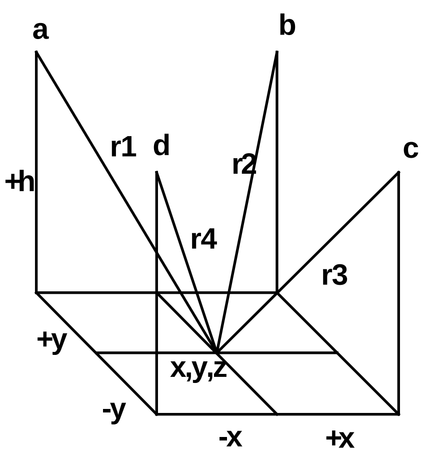

Figure 8. Schematic of string reel positioner with coordinate system and variables for equations of motion defined.

Based on the schematic of Figure 8 equations to determine string length based on object position are:

$$(x_a - x)^2 + (y_a - y)^2 + (z_a - z)^2 = r_1^2$$

$$(x_b - x)^2 + (y_b - y)^2 + (z_b - z)^2 = r_2^2$$

$$(x_c - x)^2 + (y_c - y)^2 + (z_c - z)^2 = r_3^2$$

$$(x_d - x)^2 + (y_d - y)^2 + (z_d - z)^2 = r_4^2$$

where the value r_i is the distance from the object position to the pulley position.

IX. Electrical Control System

The electrical control system consists of an industrial PC located in a standard 19" control rack. The PC will be the central hub for all communication and control of both the string reel system and the linear positioning of the rail system component, e.g. the pylon. There will be a total of six motion controller/drivers: two stepper controllers and four servo controller. The two stepper controllers will be used for moving the rail positioning components and operating the pylon spline drive. The four servo controllers will be used to operate the string reels. All communication will be done over a TCP/IP (ethernet) backbone and each of the six motion controls use Galil™ boxed hardware inside.

X. Software

Since the full system does not have to be run in a real time environment a Windows based OS (Windows 7) was chosen because of being both easily available and is the most familiar to office personnel. The PC will be running two separate LabView™ written programs. One program will be to communicate and control the stepper motors used by the linear positioners and the pylon. The other program will be used to control the string reel positioning system. The linear position software program is a relatively straight forward being that most all moves are done with simple move from point A to point B. The string positioning system is quite a more difficult program being that in most moves all four motors are running at once.

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