A Planar Positioning System for Antennas

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***Abstract*—We designed and built a low budget planar positioning system for antennas for applications such as through-wall imaging. Key constraints were: a budget under $700, minimize vibrations due to moving parts, reliability, accuracy, size, producibility, and simplicity. The positioning system will be referred to as the structure. The structure consists of a horizontal and a vertical axis, which is fabricated from aluminum extrusions as main supports. Analysis shows that for this budget aluminum is an excellent option for the physical build, because of its light weight, durability, and low cost.**

I. Introduction

The development of low budget systems to be used for testing antenna positioning is considered because the demand for reliable apparatuses that are not costly are essential to radar studies. One example is measurements for Radio Frequency Tomography that has many potential applications, most notably underground imaging, through-wall imaging, and detection of cracks in reinforced concrete structures [1-3].

In our experiment the antennas are placed on planar positioning systems meaning that the antennas will move about the vertical and horizontal axes with respect to the ground, shown as Fig. 1. This configuration allows a two-dimensional survey of electromagnetic scattering phenomena for an object under investigation, for example, a reinforced concrete cylinder, to further map its permittivity profile for crack identifications. To measure the fields scattered by the concrete, the receivers can be located along the rail on the opposite side of the concrete from transmitter. Though infinitely long rails will be ideal for acquiring entire scattered fields, the scanning range should be long enough compared with the size of the concrete. Also, in real applications, it is important that when taking measurements there is minimal disturbance, i.e. physical vibrations of the structure. The structure is the combination of a horizontal rail fixed to a vertical rail. The acquisition of physical datum takes time; ergo, it is crucial that systems should be fast, yet as accurate as possible to mitigate systematic errors.

II. System Design

It was determined that the construction would include two 1-m long aluminum rails and two 1-m tall aluminum rails. Lead screws, otherwise known as power screws or translation screws, are used to move the antennas into their various positions. In the setup, the lead screws are 8 mm, meaning that every time the lead screw makes one full rotation it will move a lead screw nut exactly 8 mm along the lead screw. This is considered as a step in our experiment. Sitting on these lead screws are 1.5-inch aluminum channels that act as carts. The cart has four legs with high-density acetal plastic wheels with bearings that fit proprietarily into the aluminum extrusion's sides. The lead screw nuts are fixed onto one side of these aluminum channels, serve to affix the cart and allow it to be pulled or pushed along the lead screws. Fig. 1 shows the overall structure. Similarly, Fig. 2 shows a detailed close-up of the positioner, the one displayed is of the horizontal rail.

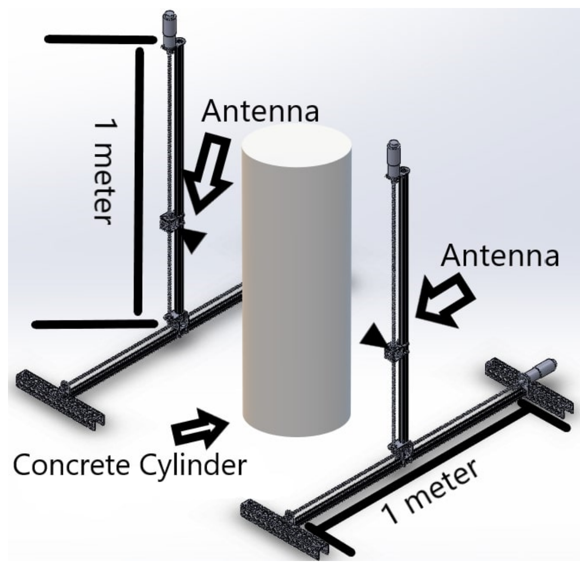

Fig. 1. The overall setup of the structures, with relations to length, width and height.

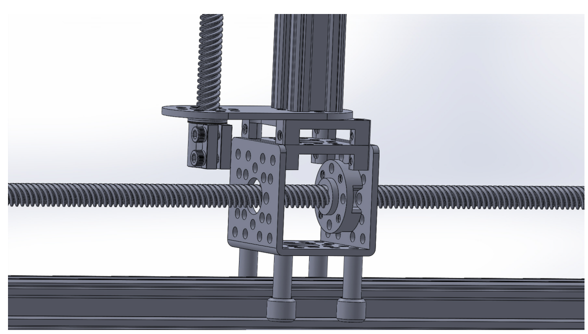

Fig. 2. The detailed setup of the positioner on the horizontal rail.

III. Constraints and Calculations

Our current benchmark, and therefore our worst-case scenario is that each measurement, including the travel time from each position, takes approximately 10 s. Additionally, each rail can reliably make 90 measurable positions within the 1 mm accuracy constraint that has been prescribed for the project. As a result, the longest time for a complete set of measurements spanning over all the possible positions is estimated to take 22.5 hours per structure as

$$\begin{aligned} &8100\, step/structure \times 10\, s/step \div 3600\, s/hr \\ &= 22.5\, hr/structure. \end{aligned} \tag{1}$$

Further improvements will be made to reduce total time of a complete scan.

Larger antennas may be mounted to these structures but the planetary gear motors that are being used will stall at a torque of 215 kgf cm. Of course, the vertical rails would likely bow if the antennas were more than 1 kg heavy due to how the weight from the antenna is distributed onto the vertical rail. Furthermore, antenna weight restrictions should be considered because of how the vertical rail and the horizontal rail are connected, their mating point is held together by four screws. An equally valid weight constraint is imposed because the weight from the vertical rail is being directed downwards onto the cart of the horizontal rail which is being supported by the horizontal lead screw and the high-density acetal wheels.

IV. Control System

The control system, by which these systems operate are Arduino Uno R3 microcontrollers [4]; they have plenty of processing power and are cost-effective. To command the motors, L289N motor drivers [5] are used. An Arduino relays to a L289N motor driver the instructions to a single structure which in turn will drive two separate DC motors; one motor positions the horizontal axis and the other positions the vertical axis. The screws are then revolved by planetary gear motors, specifically at 32 RPM (rotations per minute) at 12 V DC. The motor drivers are powered up with 12 V 2 A DC power supplies connected to AC power outlets as are the Arduino Uno R3s. Four power supplies are used in total for this project.

V. Conclusions and Future Considerations

The usage of aluminum over another metal such as steel is primarily due to cost and weight. Aluminum is also naturally resistant to corrosion, does not rust, and is also nonmagnetic. The motors we used would likely be unable to support the almost two-and-a-half times heavier steel components. All the components we used, except for the power supplies, wires, Arduino Uno R3s and L289N motor drivers were purchased through a single retailer, Servocity [6]. This allowed us to build a skillfully constructed structure, but it also limited us to using proprietary components that Servocity sells. Future designs could be made using generically fabricated aluminum from a variety of sources, which would likely cut down the overhead cost. The lead screw mechanisms have two major advantages over other linear motion mechanisms: high degree of accuracy in motion and a lack of noise [7].

With quicker motors we could move from step to step faster, but there is a limit to how fast lead screws should be safely moved. This limit is due to friction caused by the lead screw interacting with the lead screw nut. We could safely increase the RPM of the motors to something such as 437 RPM, but then finer tuning of the control system to stop for 1 cm incremented steps would be needed. The motors have encoders built into them, specifically these are Hall Effect Encoders. If the encoders could be programmed into the code, this would increase the accuracy of our system because we would then be counting steps in countable events based on the motors rotation. This contrasts with the current method of position tracking, which is simply a well-timed pulse-width module of approximately two seconds to make the lead screw nut move approximately one centimeter.

In the future, tests involving radio frequency signals for through-wall imaging will be performed. We will determine how to maximize the time out of the experiments trials, because we will be using a network analyzer in conjunction with the given control system for the structure. Another next improvement is to use systems engineering software such as LabVIEW, because of its applications for tests, measurements, and control with related hardware [8].

Acknowledgement

This research was supported by the US Army Research Laboratory (ARL) under Army Research Laboratory award number W911NF-17-1-0525. Their support is greatly appreciated.

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