Open access • Proceedings Article • DOI:10.1109/EUCAP.2012.6206720

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Institutions: United States Department of the Army

Published on: 26 Mar 2012 - European Conference on Antennas and Propagation

Topics: Antenna (radio)

Outdoor Far-Field Antenna Measurements System for Testing of Large Vehicles

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Abstract— **The Electronic Proving Ground's Antenna Test Facility at Fort Huachuca, Arizona has some of the most interesting testing structures in the world. These structures include a wooden Arc measurements system with a 23 m radius, a 30 m tower, and a compact range with an 18 m quiet zone. All of these structures are outdoors and support testing from UHF to mm frequencies on antenna systems mounted on large land and air vehicles. This paper describes the ranges supported by these structures (some of which were built in the late 1960's) and the efforts made to keep these ranges current. This paper also describes an economical approach to arc range design which moves the arc instead of the vehicles. This paper discusses plans to build one of these systems outdoors at EPG within a limited budget.**

Keywords-component; Outdoor Far Field measurements, Spherical far field measurements, Range Design, Range modernization

I. Introduction

The Electronic Proving Ground's (EPG) Antenna Test Facility (ATF) (Fig 1 & 2), at Fort (Ft.) Huachuca, measures antenna systems over a frequency spectrum of 20 MHz to 90 GHz. The antenna systems that are tested at the ATF can range in size from several centimeters to 13 m in diameter and can either be measured off the vehicle (stand alone or mounted on a ground plane) or mounted on a vehicle. Vehicles up to 72,500 kg can be measured at this facility. With the added capability of a new Arc range the weight limitation is eliminated [1].

Figure 1. ATF – Compact Range, Arc, and Low Observable Tower

Figure 2. ATF – Arc and Low Observable Tower

Advances in antenna measurement capability over the past 30 years has made it possible to quickly measure antenna systems at higher frequencies located indoors in chambers next to engineering and production resources. The lower frequency spectrum and its requirement for outdoor measurement capabilities have been closed down at a record pace. Much of this is due to the cost of the real estate required for these measurements and the availability of low frequency spectrum interference sites. Finding a low frequency spectrum interference site requires that these be located in remote areas which makes recruiting qualified engineers an issue.

Wooden testing structures used outdoors tend to degrade quickly and require rigorous maintenance programs to maintain their measurement capability. Testing large vehicles which weigh as much as 72,500 kg require large, slow moving positioning systems with large radius measurement structures to characterize these vehicles using a spherical coordinate system.

Typically the far-field is defined as in equation 1 or distances greater than 10λ. Measurements between 3λ and 10λ is defined as the near-field, and frequencies below 3λ is considered the reactive (or the evanescence zone) near-field. Wavelengths at 30 MHz, regardless of the aperture requirements would require a 30 m radius to keep the measurements out of the reactive near-field.

$$2d^2/\lambda \qquad (1)$$

Where d is the longest dimension of the antenna aperture. [3]

Designing a low frequency outdoor measurement system for large vehicles within a modest budget requires large amounts of innovation and research. Essentially anyone with an unlimited budget can purchase a measurement system; the easiest way is to simply take your funding to one of the suppliers of antenna measurement systems. Using these suppliers may get you what you want but factors such as whether your application fits into their line of products. If the supplier is not busy and the risk is low, will determine if they will design a custom system for you. Either way, you will likely be locked into the supplier's products for its life. Unfortunately, we neither had the money nor could we fit our applications around the supplier's off-the-shelf products. The ideal measurement system would have been to take the best product from each supplier (they each have at least one modern innovation); however, these suppliers are very competitive and will not allow this to happen.

II. Test Site

Ft. Huachuca is located at the intersection of the Sonora and Mohave deserts in southern Arizona in the United States. The low frequency spectrum interference, favorable weather and availability of large sections of land allow testing at lower frequencies year around. Recruitment from the State's Universities (Arizona State University, Northern Arizona and the University of Arizona) and their strong electromagnetic study programs provides adequate engineering resources.

The site has supported measurements on antenna structures since the late 1960's and was chosen because of its weather (low humidity) and low population density. The low humidity has extended the life of the wooden test structures. As the population and technology advances the RF spectrum started to show more activity. To prevent further contamination of the RF spectrum Ft. Huachuca petitioned the state of Arizona to pass legislation that designates the area as a protected RF environment. The state of Arizona passed legislation in 2008 that allowed RF testing but restricted RF encroachment to the area [2]. The facility has a radio frequency authorization to transmit from 20 MHz to 90 GHz without any interruptions in frequency coverage.

III. Test structures

The test structures at Ft. Huachuca are versatile enough to measure antennas on a large vehicle or removal of the antennas and measure on a 'stand alone" basis. The range supports a 23 m radius azimuth/elevation near-field/far-field measurement system (Figs. 3 & 4), two 152 m far field ranges with a 30 m tall tower, a 18 m quiet zone compact range (Fig. 4) and a 7 axis planar, cylindrical, and spherical near-field range (Fig. 6). Except for the near-field range, these ranges operate outdoors. The arc and 152 m ranges are constructed above ground level and of wood (Fig. 2), which is useful for negative angled pattern measurement levels and for the low dielectric properties of the material, respectively. The range can support measurements from 20 MHz to 90 GHz.

A. Arc

The Arc range provides a mechanical spherical coordinate system that allows azimuth (ϕ) and elevation (θ) collection grids for far-field or near-field measurements. The azimuth axis, diameter 18 m, is capable of supporting and rotating 72,500 kg 360 degrees in azimuth using an inverted railroad rail and friction drive system underground. Vehicles can be driven onto its surface. For elevated measurements, three fiberglass racks can be placed underneath the vehicle (Fig. 3) and negative angles can be measured to as low as -30 degrees below the 0 degree elevation.

B. Low Observable Tower

The low observable tower is constructed of non-metallic material above the ground level and is 30 m tall. It can be used as either the source or receive tower and the range can be configured as a line of sight or reflection range. This tower is located 152 m from the arc azimuth table and has a non-metallic drive system on the east and west sides of the tower that can transport a sled from 0 to 30 m (Fig. 5, 6).

The Smaller table, which is located 152 m from the low observable tower on the opposite side of the arc range, has a 9 m diameter table and is capable of moving 36,300 kg. The positioning system is located below grade. This range is typically used for ground level measurements.

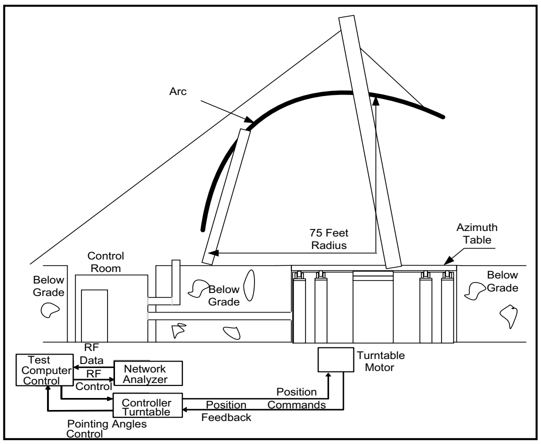

Figure 3 Arc – Underground/Below Grade Structure

C. *Compact Range*

The compact range, with 18 m quiet zone, was designed and installed by Georgia Tech Research Institute (GTRI) group. This was the largest outdoor compact range in the world when it was built. The range is designed to maintain its specified amplitude ripple and phase taper for frequencies in the 4 to 40 GHz frequency bands (Fig. 4).

D. *Indoor Near Field*

The Near-field range is the newest range at Ft. Huachuca; it was built in 2012 to provide an engineering tool for the resident engineering staff as a quick verification for standalone measurements. The range can be configured as a far-field, planar, cylindrical or spherical near-field range. The frequency range of operation is 500 MHz to 90 GHz.

Figure 4. Compact Range

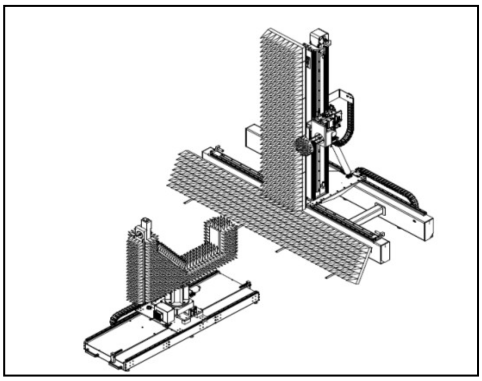

Figure 5. Near-Field Range

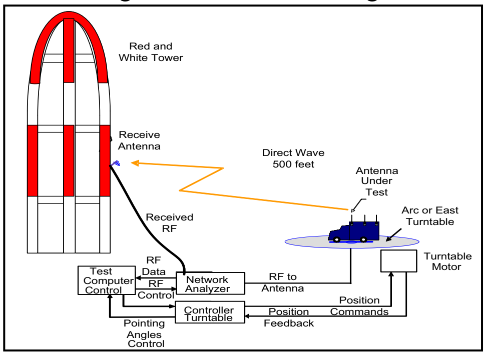

Figure 6. ATF Ground Reflection Range

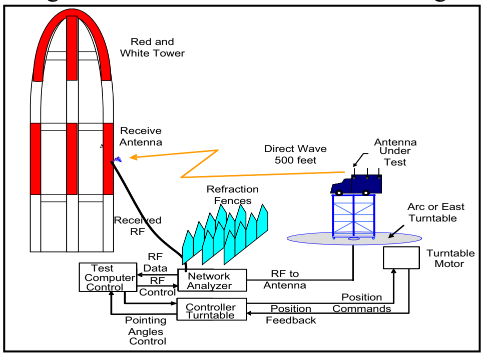

Figure 7. Elevated Range Test

IV. NEW CAPABILITY

The arc is the workhorse of the ATF. It is in use for two shifts a day and typically 7 days per week. The technology used to design the positioning system was developed in the 1960's. In order to modernize the range, it will require that
the range be shut down for a year.. To design a new range that maintains the critical capabilities of the existing arc range requires that a different concept of measurements be employed. The azimuth turntable used on the existing Arc range is made of steel and uses an inverted rail road type rail system with roller bearing and a friction drive system. Replacement of this azimuth table system would cost more than one million dollars by itself and would take more than a year to manufacture. A new pit and concrete bunker would need to be installed and would cost to well over a million dollars.

The arc elevation axis would cost an additional estimated two million dollars. A conservative estimate to replace this older system would be more than five million dollars.

The design of this type of system has some limitations; one of the biggest limitations is the load weight limit on the azimuth turntable. Moving the 72,500 kg (the estimated weight of the steel table) table and another 72,500 kg test load requires a carefully constructed movement algorithm which is used to calculate the movement sequence and needs to be changed when lighter loads are placed on the table. The engineering staff decided that moving the arc instead of the vehicle may be a less expensive method of achieving the same azimuth/elevation coordinates in both the initial design and over the life of the positioning system. National Institute of Standards and Technology (NIST) was consulted on the mechanical specifications needed to achieve the required accuracy and set the upper frequency boundary so the cost vs. measurement capability could be optimized [1].

The design of this system utilizes a circular track built on a concrete foundation that is designed to use the geothermal properties of the Arizona desert to maintain a constant foundation temperature. Circular way track rails/bearings will be installed on the foundation and moves a tower that supports a 15 m radius articulated arm elevation system. The height of the elevation system is adjustable from 1 m (ground level) to 6 m so that it can be used for elevated testing (Fig. 8, 9).

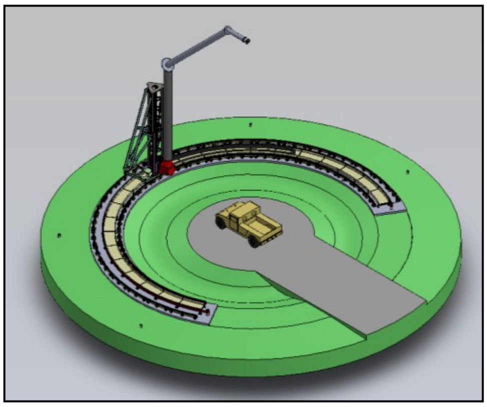

Figure 8 Arc Range Track System

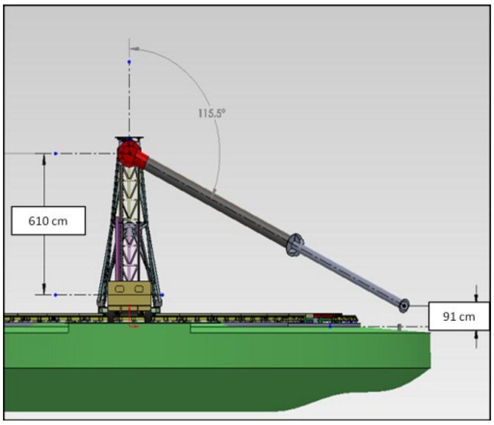

Figure 9. Arc Range Elevation System

Moving the elevation axis along a fixed circular track allows the drive system be tuned for one load. The articulated arm allows for a 180 degrees elevation movement and reduces the azimuth to a 180 degrees movement. This technique allows for a complete hemisphere measurement at elevations 1m to 6 m elevated radius that allows negative angles measurements 20 degrees below the zero. The positioning system is designed to over scan in azimuth from the typical +/- 90 degrees. This over scan adds an additional 10 degrees on each side (+/- 100 degrees or a total of 200 degrees). The final coordinate travel range is ± 100 degrees in azimuth, ± 110 degrees in elevation and 1 to 6 m elevation. A real time z correction axis is also installed at the probe mounting location to allow for coordinate adjustments. This system will allow a 15 m radius arc movement in azimuth and elevation.

V. SUMMARY

The ATF at Ft. Huachuca (Fig. 1) has some very unique positioning systems and measurement capability. A new approach to outdoor arc measurement has been discussed, one which reduces the overall cost of a azimuth and elevation with a 15 m radius positioning system from $5 M to $2M. The ATF with new arc will be available for tour during AMTA 2014, which will be hosted by Ft. Huachuca, Raytheon, University of Arizona, and Arizona State University, in Tucson, Arizona, US.

ACKNOWLEDGMENT

The authors would like to extend their thanks to the ATEC and EPG Technical Directors for their support.

REFERENCES

[1] Francis, Michael H, ESTIMATION OF FAR-FIELD ERRORS DUE TO MECHANICAL ERRORS IN SPHERICAL NEAR-FIELD SCANNING, The National Institute of Standards and Technology, 325 Broadway, Boulder, CO 80305, Email:

[2] Arizona State Bill 1387 Articles 5-12, Chapter 3-5).

[3] Balanis, Constantine A, Modern Antenna Handbook. John Wiley & Sons, Inc. pp 931-954. 2008

[4] Microwave Antenna Measurements, MI Technologies, J.S. Hollis, T.J. Lyons and L. Clayton, 1979