SYSTEM DESIGN OF A COMPACT RANGE VERIFICATION FACILITY FOR LARGE MULTI-BAND RADOMES

Carl W. Sirles

ATDS Howland
4540 Atwater Court, Suite 107
Buford, GA 30518

Abstract

Compact ranges have found wide use in the parametric characterization of high performance radomes such as those found on modern military aircraft. A properly designed compact range facility provides a stable, repeatable test environment suitable for the measurement of small variations in antenna boresight position (beam deflection), antenna pattern distortion, and transmission loss. Radomes have increased in complexity from small structures housing a single antenna to multi-band, multi-system structures large enough to stand inside. Similarly, compact range reflectors have increased in size; commercial units available today provide quiet zone extents of 12 feet or larger. This paper describes the system design and performance of a compact range test facility designed to test a C-130 Combat Talon II nose radome measuring 7 feet in length and diameter. The facility was constructed at Robins AFB, GA, and is in operation.

A description of the facility and its major subsystems is given. Sizing of the chamber and layout of equipment is described. Chamber electromagnetic design considerations are discussed. Electromagnetic design was complicated by the physical size of the structure required to mount the radome, by the fact that multiple antennas and gimbals are present inside the radome during testing, and by the need to use a broadband feed to eliminate mechanical feed changes. Absorber layout and control of spurious reflections is discussed. Electromagnetic performance data is presented.

Keywords: Compact Ranges, Radome Measurements

1. Introduction

Many aircraft radome structures are physically large, and operate at frequencies up to Ku-band. Prior to Compact Antenna Range technology, outdoor ranges were required to obtain far-field conditions and quiet zone field purity over the radome aperture. As compact range reflectors have increased in size, there has been a steady push to move radome testing into an indoor environment. Large radome structures present unique challenges to the facility designer. Electromagnetic performance of the facility is greatly influenced by the structures required to support and handle the radomes and their interaction with the compact range reflector.

The Combat Talon II (CT-II) nose radome is physically very large: approximately 7 feet in length and diameter. The radome houses multiple radar and avionics systems operating at different frequencies and using different radome aperture areas. Boresight error (beam deflection), transmission loss, and antenna pattern distortion are tightly specified and must be measured over a major portion of the radome surface. Large amounts of test data must be acquired and processed to determine radome performance.

The CT-II Radome Verification System (RAVS) was designed to provide a highly accurate indoor measurement environment and to minimize radome test time. To accomplish these two goals required that all operating aspects of the measurement facility be considered as a system and designed to function together efficiently.

This paper describes the RAVS facility, details its electromagnetic design, and presents measured electromagnetic performance data.

2. Facility Description

The RAVS facility, shown in Figure 1, consists of a shielded anechoic chamber housed within a stand-alone host building. The host building provides an environmental buffer for the anechoic chamber. The temperature within the anechoic chamber is controlled to within 3 degrees and the humidity is held within 15 percent to maintain a stable test environment. The host building also provides space for radome preparation and fixture storage.

The anechoic chamber and control room use an architecturally integrated shielding design to provide 60 dB shielding attenuation in the UHF and microwave frequency range. All signal and power penetrations into the shielded area are filtered to prevent unwanted signal leakage.

The anechoic chamber houses an MI Technologies 5708 compact range reflector and feed positioner, an Oribit/FR multi-axis radome test positioner, and several items of support equipment. The control room houses an Orbit/FR measurement instrumentation system, dual PC workstations for data acquisition and analysis, and graphics printers for hardcopy presentation of measurement results. The RF measurement system is based on the HP 8530 receiver, and the data acquistion software system is based on the Orbit/FR 959 Antenna Measurement Workstation software system. A custom data analysis/data output software package was developed for Orbit/FR by ISAR, Inc. A photograph of the chamber is shown in Figure 2.

The CT-II radome is large, bulky and difficult to handle. The radome is transported on a specially designed cushioned pallet during repair and storage. The RAVS facility is equipped with an electric forklift which will interface directly with the radome pallet. The forklift is used to move the radome around in the preparation area, and to lift the radome and pallet into location on the test positioner during radome mount/dismount operations, as shown in Figure 3.

The size, shape, and handling requirements of the CT-II radome require that it be loaded in a horizontal position. The radome is mounted to the test positioner directly from the transport pallet. Since the range centerline is 15' above the chamber floor, a permanent personnel platform is attached to the test positioner for radome mounting and for test antenna/gimbal servicing. The platform is accessed by removable ladder platforms.

3. Anechoic Chamber Layout

The CT-II radome requires a Quiet Zone size at least 8 feet in diameter. An MI Technologies 5708 compact range reflector was selected for this application; Quiet Zone size for this reflector is 8' H x 12' W x 12' L. The RAVS anechoic chamber was sized to support this reflector system, the CT-II test postioner, and the auxillary equipment required for radome testing (Ref 1). Chamber dimensions (without absorber) are 75' L x 40' W x 30' H. An elevation view of the chamber and measurement equipment is shown in Figure 4.

The chamber was equipped with a 12' H x 12' W shielded door located to allow direct forklift access to the chamber and test positioner for radome mounting.

4. Electromagnetic Design Considerations

Radiated measurement accuracy on a compact antenna range is determined primarily by the quality of the reflector/feed system if chamber reflections are suppressed sufficiently. The RAVS measurement system operates from 8 – 18 GHz and has a sidelobe measurement accuracy of ±2.25 dB for 40 dB sidelobes. The chamber wall surfaces were covered with 12" pyramidal absorber and the backwall was covered with 18" to limit reflected energy entering the Quiet Zone to less than 50 dB below the direct Quiet Zone energy.

The RAVS chamber presented several additional electromagnetic design challenges:

- Broadband, multi-polarization operation required the development of a specialized feed for the compact range.
- Easy access to the test positioner was required to mount/dismount the radome.
- A physically massive test postioner was required for the radome and test antenna array.
- Use of elevation scans was required during pattern distortion testing of the radome to minimize test time.

Each of these issues is discussed in some detail below.

The CT-II radome operates at both X- and Ku-band with both linear and circular polarization. The measurement instrumentation system is highly automated and manual changeout of the feed antenna was prohibited by test time limitations. Broadband feeds and automated feed changing systems were investigated; it was determined that a broadband feed with high speed polarization switching capability was required to meet the RAVS requirement. A broadband feed utilizing a Sinuous antenna as the radiating element was developed specifically for the RAVS facility (Ref 2). The feed can be electronically switched between H, V, RCP, and LCP polarizations and can be configured to operate from 2-18 GHz. For the RAVS application, the feed was optimized to operate from 8 – 18 GHz. Feed linear polarized cross-polarization ratio is typically –25 dB, compared to –30 dB minimum for standard MI Technologies compact range feeds. Circular polarization axial ratio is typically 2 dB. This performance is adequate for testing of the CT-II radome, and a reasonable trade-off to obtain broadband, polarization switchable operation.

CT-II radome mounting operations require the positioning of a forklift and mobile access ladders around the test positioner. It was desired to leave the floor area surrounding the test positioner clear of absorber to minimize radome mounting time. An absorber fence was placed on either side of the feed positioner to minimize the energy level on the chamber floor behind the feed positioner. Analysis of the Quiet Zone field indicated that scattering from the top of the fence is minimal if the fence height is less than 60". A 48" high fence was used and the top of the fence was treated with absorber serrations to further limit diffraction.

Highly accurate spatial postioning (0.005 deg) of the radome and test antennas is required for testing of the CT-II radome. The test positioner and radome mounting structure are consequently very large and can substantially impact the electromagnetic test environment. Two primary areas of concern were addressed: mutual coupling and reflections from the positioner structure.

Multiple reflections between the test antenna or test positioner and the compact range feed antenna are called mutual coupling. If the impedance match of the antennas is reasonably good and the test postioner structure is small or absorber covered, this effect is usually small. However, the radome support structure on the RAVS test positioner is large and flat and can reflect significant energy back to the feed antenna. Further, multiple test antennas are present in the CT-II radome; the out-of-band antennas may reflect significant energy back to the feed antenna and then back to the in-band antenna, causing measurement errors. To counter these problems, the radome mounting structure was lined with 3" pyramidal absorber over as much of the surface as practical. Further, the CT-II test scenario was configured to direct the main beam of the out-of-band antenna away from boresight during radiation pattern measurements. Residual measurement error due to mutual coupling is typically 0.25 dB, measured at boresight.

The CT-II test positioner is heavily counterweighted to minimize bending moment about the elevation axis. The counterweights do not intrude into the Quiet Zone, but can reflect energy into the test antennas. To limit these reflections, the counterweights and the front of the personnel platform on the positioner were covered with 8" and 12" absorber. Residual reflections from these surfaces are less than 45 dB below the Quiet Zone signal level.

Elevation axis scans were required to evaluate beam deflection and pattern distortion on the CT-II radome. Elevation axis scans on a compact range whose focus is in the elevation plane can be difficult due to interference from feed backlobes, the feed positioner structure, and the test positioner structure. Considerable experimental effort was required to isolate and minimize these reflections in the RAVS system. It was determined that feed backlobes were sufficiently low that they were not a problem, but reflections between the upper part of the test positioner and the back of the feed positioner or slide were significant, typically 25 dB below the Quiet Zone signal level. Judicious application of absorber to these areas reduced the reflection levels to –45 dB.

5. Measured Performance

Field Probes were performed on the RAVS compact range facility to evaluate reflector performance. Figure 5 shows typical amplitude field probes at C-Band. Figures 6 and 7 compare field probes at X- and Ku-Band using the Sinuous feed and MI Technologies Series 32 compact range feeds. Table 1 summarizes typical reflector performance.

Band	Amp Taper	Amp Ripple	Phase Variation
C	0.5-1.0 dB	0.2-0.4 dB	5-10 deg
X	0.5-1.0 dB	0.3-0.5 dB	< 10 deg
Ku	0.5-1.0 dB	0.3-0.7 dB	< 10 deg

Table 1. RAVS Compact Range Quiet Zone Performance

Pattern comparison measurements were made using the CT-II antennas to determine the composite effect of residual chamber reflections on measurement accuracy. Sidelobe measurement accuracy is typically ±1 dB for 30 dB sidelobe levels.

6. Conclusions

The successful implementation of a compact range measurement facility designed to test the Combat Talon II nose radome has been described. This radome is a physically large, multi-band, high performance radome requiring acquisition and analysis of large amounts of test data to adequately determine radome performance.

The RAVS facility was designed as a turnkey system to provide high accuracy measurements in a time efficient manner. A broadband compact range feed was developed to eliminate the need to change feeds during the measurement process. Radome handling requirements were factored into the electromagnetic design of the facility. Electromagnetic performance of the facility was demonstrated to be adequate for accurate measurement of radome characteristics. The facility is presently in operation at Robins AFB, GA.

7. Acknowledgements

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The RAVS facility has resulted from the unique application of products and design talents from leading companies in the antenna measurement industry: ATDS provided system engineering and electromagnetic design for the facility, proof-of-performance testing, and preparation of operation & maintenance procedures and military formatted manuals; Lehman Chambers was the Prime Contractor and constructed the host building and anechoic chamber; MI Technologies supplied the compact range reflector and feed positioner; Orbit/FR supplied the test positioner, measurement system and operating software; ISAR provided the custom radome data analysis software.

8. References

1. MI Technologies, LLP, "Facility Recommendations – 5708 Compact Range", June, 1989.
2. Carl W. Sirles, "A Broadband Polarization Selectable Feed for Compact Range Applications", Antenna Measurement Techniques Association Symposium Proceedings, October, 2000.

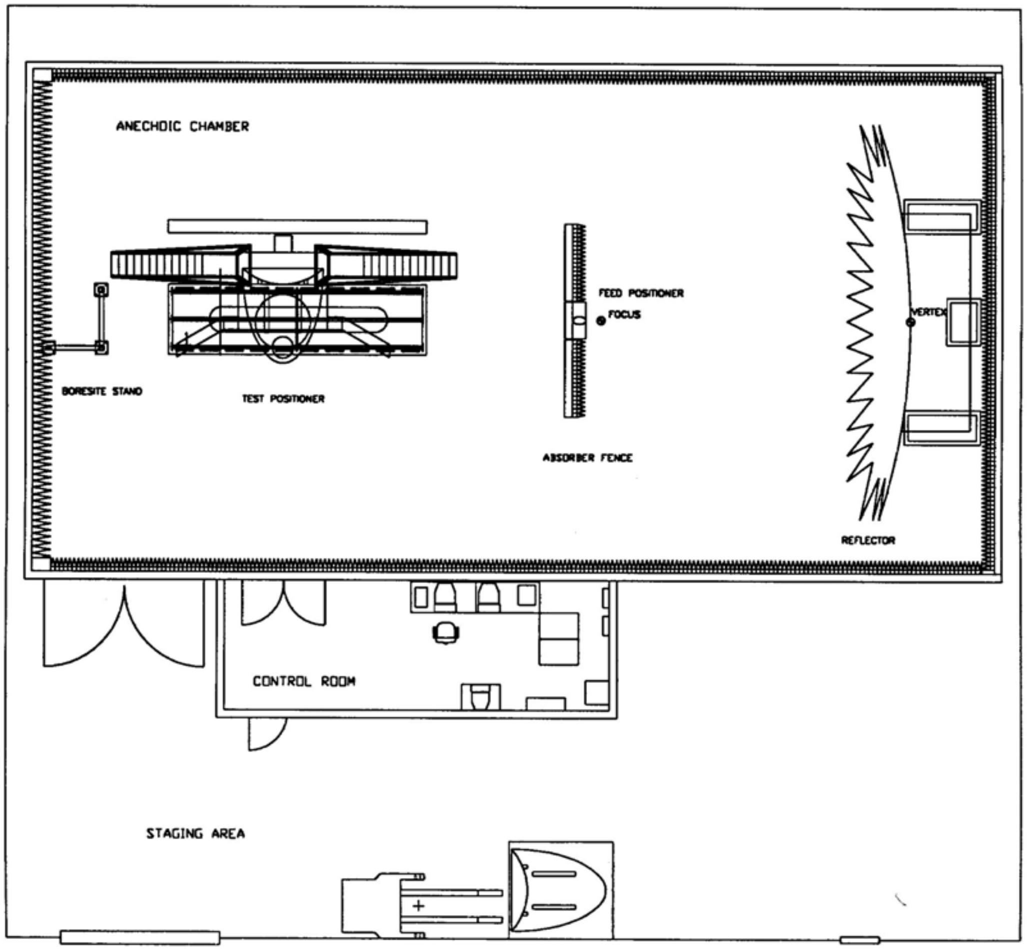

Figure 1. RAVS Facility Plan View

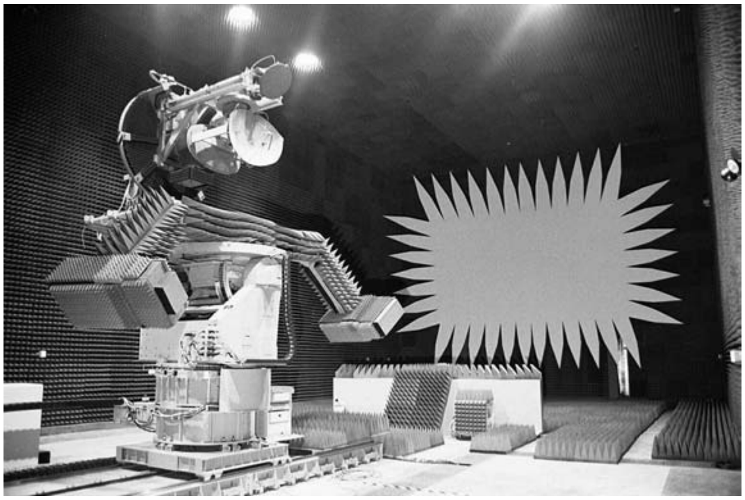

Figure 2. RAVS Anechoic Chamber

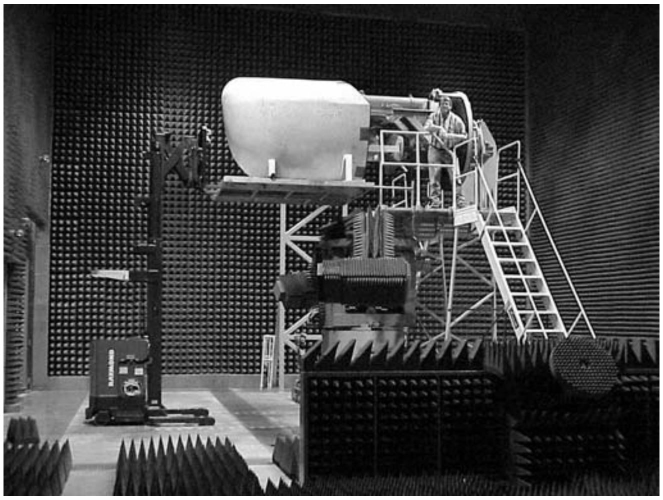

Figure 3. RAVS Radome Mounting Operation

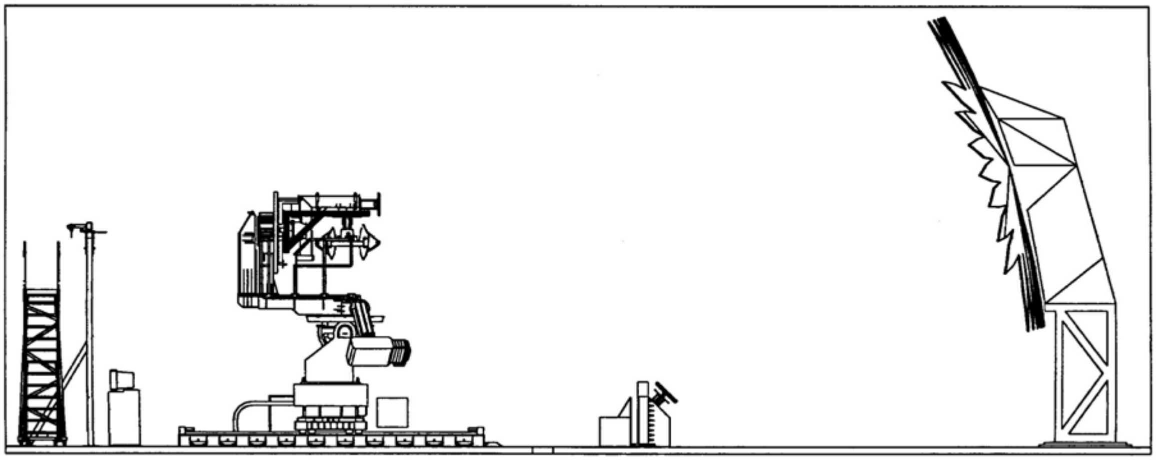

Figure 4. RAVS Chamber Equipment - Elevation View

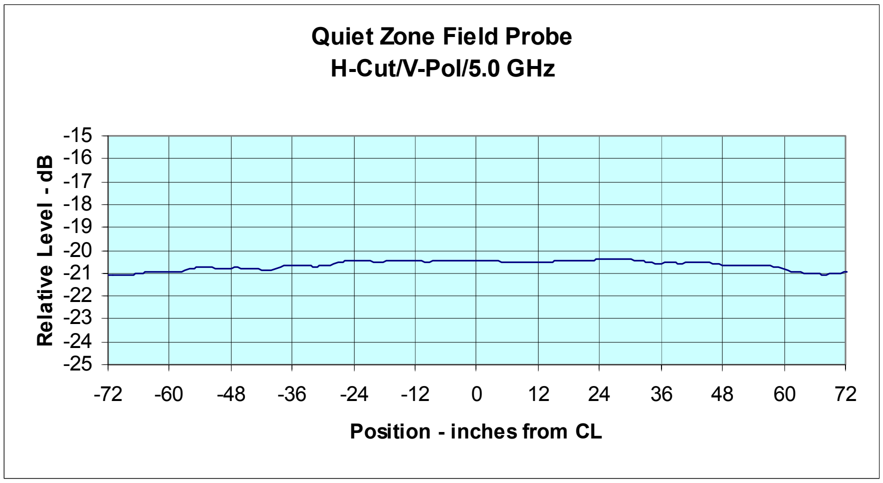

Figure 5. C-Band Quiet Zone Field Probe

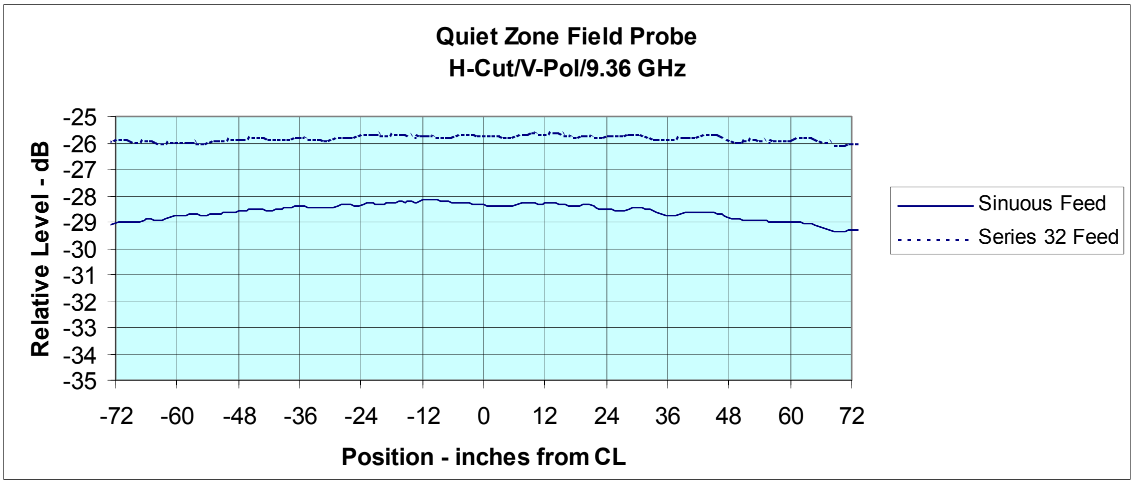

Figure 6. X-Band Quiet Zone Field Probes

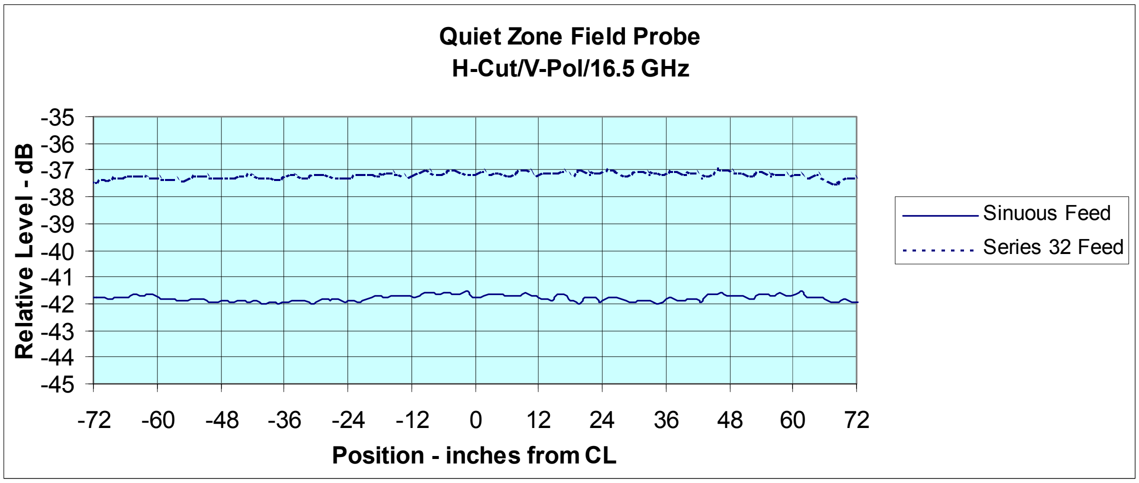

Figure 7. Ku-Band Quiet Zone Field Probes