Changes In The DO-213 Standard For Commercial Nose-Radome Testing

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Abstract—“RTCA DO-213 Minimum Operational Performance Standards For Nose-Mounted Radomes” [1] is a document frequently referenced in nose-radome testing requirements for commercial aircraft. This document was produced and is maintained by the Radio Technical Commission for Aeronautics (RTCA). The specifications of weather-radar systems have recently changed within RTCA’s DO-220A [2], and as a result DO-213 was updated to DO-213A [3] in March, 2016, to ensure that radome requirements are consistent with those of the weather radar.

In addition to the new requirements for radome evaluation, several existing requirements were clarified. These clarifications addressed such topics as suitability of near-field measurements, proper procedures and processing, and appropriate measurement geometries.

RTCA coordinated the document revision, with the bulk of the technical inputs coming from a broad-based working group. This working group had representatives from radar, aircraft, and radome manufacturers, government agencies, and providers and users of radome-testing systems. When requirements were added or when common practice conflicted with existing requirements, considerable effort and analysis were employed to ensure that each change or clarification was truly required. Nevertheless, DO-213A has some significant impacts to many existing radome-testing facilities.

This paper discusses the significant changes from DO-213 to DO-213A and their implications for radome-testing facilities, concentrating on after-repair radome electrical testing.

Keywords: Radome characterization, DO-213, weather radar

I. INTRODUCTION

DO-213 [1] is a document that is very familiar to most people involved in commercial nose-radome testing. It was written for a very broad audience, including those involved with radome design, qualification, environmental testing, production, repair, and RF testing. It concentrates on radome performance requirements, and while it does describe the RF tests that must be performed, those descriptions sometimes lack clarity. Many of the facilities that perform after-repair RF testing have far more expertise in radome repair than in RF testing, such that misinterpretations of the requirements have been frequent and sometimes significant. Furthermore, those who certify test facilities as being DO-213 compliant might not be well versed in RF testing and kinematics, and must lean heavily upon DO-213’s sometimes vague requirement descriptions. As a result, many of the certified DO-213 after-repair test facilities do not actually meet the DO-213 requirements.

Several of this paper’s authors were members of the DO-213A working group, and made significant technical contributions. NSI-MI’s goal in this effort was to help ensure that the document’s description of the RF-testing requirements was clear, complete, concise, and not unnecessarily restrictive. At no time did NSI-MI define what those requirements were, but instead worked closely with radar and aircraft manufacturers to understand the details of their requirements.

II. REQUIREMENTS CHANGES

A. Range Length

DO-213 specifically allowed an “Indoor Far-Field” geometry with a range length of $D^2/2\lambda$, or $\frac{1}{4}$ the standard far-field distance with $90^\circ$ of parabolic phase taper. DO-213A has reworked the requirements to describe the necessary field characteristics rather than the geometries that yield them, and has restricted phase taper to $22.5^\circ$, the traditional threshold corresponding to $2D/\lambda$. This change by itself has eliminated the conventional indoor far-field geometry. When measuring patterns, DO-213A has also increased the quantity $D$ from the system antenna’s diameter to the diameter needed to include any portion of the radome in front of the system antenna’s aperture during the course of testing.

This tightening of the requirements was not undertaken lightly. The working group concluded from a combination of computer modeling and historical measurements that the $90^\circ$ phase taper inherent in a $D^2/2\lambda$ geometry could easily cause either false positives or false negatives in radome testing.

B. SLL-Increase Testing and Limits

DO-213 called out after-repair side-lobe testing only for Class A radomes at a single aspect. DO-213A now requires testing at nine aspects, and includes any radomes used with forward-looking-windshear capability or those used with “other sidelobe-dependent radar functions”.

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Many existing DO-213 ranges test only transmission efficiency (TE), where the system antenna always points at the range antenna. Most of these would require a new positioning system to support the dual geometry of either TE or pattern measurements, where the system antenna rotates with the radome at specified antenna-to-radome aspects.

Absorber considerations are also very different for a range that tests only TE vs. one that can test patterns. When two directive antennas point at each other, off-axis stray signals have little impact on the measured Voltage. That is no longer the case when the system antenna scans its pattern. DO-213A calls out quiet-zone amplitude and phase ripple of \( \pm 0.5 \, \text{dB} \) and \( \pm 5^\circ \) to bound stray signals for pattern measurements.

DO-213A has modified the allowable SLL increase to remove discontinuities in the specifications. It has also removed the special cases of image lobes in Category 2 radomes. Figure 1 shows DO-213A’s specifications for SLL increase, with DO-213’s specs superimposed for comparison. The upper plot is for Category 1 radomes in Area 1 (where \( |\text{gimbal az}| \leq 25^\circ \) and \( |\text{gimbal el}| \leq 10^\circ \)). The lower plot is for Category 1 radomes outside Area 1 (Area 2) and for Category 2 radomes everywhere. Note that all after-repair testing is specified to be in Area 1.

![Image](image.jpg)

**Figure 1.** Max allowed SLL vs. reference SLL

### III. REQUIREMENTS CLARIFICATIONS

It is very difficult to write a requirements document that clearly, completely, and concisely conveys those requirements. In discussions within the working group, as well as exposure to multiple certified DO-213 test facilities, it became obvious that some clarifications were needed for many requirements already in DO-213. The goal in these clarifications was to ensure that a facility’s testing and processing are adequate to evaluate the radome’s effects on the weather radar system.

For facilities that had misinterpreted the DO-213 requirements, the clarifications in this section may effectively represent requirements changes.

#### A. Suitable Measurement Geometries

DO-213’s Section 2.4.2 listed three specific range types (compact, indoor far-field, and outdoor far-field) that would be valid for radome testing. However, Section 1.7 provided a blanket statement that other methods could be used if the results were the same. This led to some confusion over the years about whether a near-field range could be called DO-213-compliant.

DO-213A no longer lists specific allowable range layouts, though it does now specifically allow near-field techniques. The range descriptions and reference to range length have been replaced by field-quality specifications for ranges that directly illuminate the radome with an approximated plane wave. As stated in Section II, the conventional indoor far-field geometry has been effectively disallowed in DO-213A. Its quadrature phase taper is nominally \( 90^\circ \), which is far more than the \( 22.5^\circ \) now called out. DO-213A does not rule out testing at that short distance, provided that some means is found (like a compact-range reflector or a lens) to sufficiently collimate the beam.

DO-213A includes a new section that discusses and allows near-field approaches. It is important to realize that radome measurements typically place extreme fidelity demands on any range, and this is particularly true with near-field geometries. It is also important to understand that the 45 aspects called out for TE measurements represent at least 45 complete dual-polarized near-field acquisitions. Furthermore, if mutual coupling with the near-field probe perturbs the transformed pattern peak by \( \pm 0.1 \, \text{dB} \), then the number of required acquisitions doubles, with an intervening \( \lambda/4 \) translation of the probe. Instrument and cable drift over the span of these acquisitions and those of the free-space data must also be such that the far-field pattern peak is repeatable to within \( \pm 0.1 \, \text{dB} \).

IEEE-1720-2012 [4] is referenced toward making near-field measurements of sufficient quality. DO-213A also calls out comparison of the system antenna’s free-space pattern to compact-range results when first commissioning a near-field radome range.

#### B. Antenna Movement Within Radome

DO-213 imposed the following requirement (in its Paragraph 2.2) on test facilities regarding the positioning system: “Radome performance measurements require a test range that simulates the actual operation of the radome as installed over the antenna system on the aircraft. A radome/antenna positioner system shall be used that locates the test antenna within the radome at the same location as used in the aircraft installation. Gimbal sequence shall consider the order of the actual antenna system in the aircraft installation.” These requirements are fundamental to radome testing, but numerous facilities have been built and certified that fail to meet them. To prevent similar misinterpretations in the future, DO-213A has added several clarifications to these requirements along with tolerances that need to be met.
One frequent mistake in DO-213 radome-testing facilities is the stacking order of the radome positioner. DO-213’s discussion of appropriate test equipment shows several figures containing the conceptual radome positioner shown in Figure 2 [1]. While not definitive, this appears to recommend an elevation-over-azimuth radome positioner. This stacking is commonly found on after-repair radome ranges. As DO-213A now explains (in its new Appendix C), however, an el/az radome positioner is almost always inappropriate for testing the vast majority of commercial nose radomes.

To illustrate why an el/az radome positioner would be inappropriate, we first need to consider, per the DO-213 requirement, the gimbal sequence of the aircraft’s radar system. All offerings for commercial aircraft from at least Rockwell Collins and Honeywell are el/az gimbals. If we were to trace the corresponding scan lines on a translucent hemispherical radome, then it would look something like Figure 3.

If we wanted to test transmission efficiency at \([\text{Az}, \text{El}] = [-80, 20]\), then we would want the combination of antenna and radome to look like Figure 4 when viewed from the range antenna, provided that the range antenna is copolarized to the system antenna. If, as is commonly done, the system antenna is mounted on a fixed post so that it always faces the range antenna, and an el/az positioner rotates the radome to \([-80, 20]\), then we would achieve the incorrect alignment shown in Figure 5, where the antenna should be centered on the grid point in the upper corner, and should be aligned so its vertical sides are parallel to the longitude line at \(-80^\circ\) azimuth.

While we want to be testing scans of azimuth or elevation along the grid in Figure 3, the grid being tested by an el/az radome positioner is the one shown in Figure 6. Note that at the edges of azimuth travel, the radome elevation axis is very nearly a polarization axis rather than an elevation axis. The primary result is that it is not possible with limited elevation to properly test all the spots on the radome that DO-213A (or DO-213) calls out for testing. A secondary result, evident in Figure
is that the polarization vector being used for testing at these outer aspects is not the same as the one the radome would see on the aircraft.

It is easiest to envision a proper radome-positioner stackup by thinking of the radome positioner counter-steering the antenna, rather than the other way around, during transmission-efficiency measurements. We must start with the knowledge that the aircraft has an el/az gimbal. If we put our hypothetical el/az gimbal on an az/el radome positioner, or the opposite of the gimbal stackup, then the counter-rotation of the el/az/az/el stackup is trivial, where $|$radome az$| = $gimbal az, and $|$radome el$| = $gimbal el. If our radome-test system has no gimbal but uses a floor-mounted post instead, the required radome motion is the same: The post merely simulates the counter-steering of the gimbal for the radome-positioner axes.

Counter-steering would not be simple in an el/az/el/az stackup when both gimbal angles are non-zero. It is possible, though it requires non-linear equations of motion for azimuth, elevation, and range- and system-antenna-roll axes, as well as a significantly increased range of elevation travel.

DO-213A states that there are other suitable radome-positioner geometries, such as roll/az, that can effect the required motion. While the az/el radome stackup is the only one that can easily counter-steer an el/az gimbal, other geometries may prove to be more practical, particularly when using a floor-mounted post or when occasional emulation of an az/el aircraft gimbal is also needed.

C. Side-Lobe Level (SLL) Increase Determination

When a radome is placed in front of an antenna, the result can easily be a change in the number, locations, and/or levels of the antenna pattern’s side lobes. DO-213 called out allowable increases in those SLLs as a function of the free-space SLL, but offered no guidance on the algorithm to be used. A new appendix has been added to DO-213A to provide such guidance.
D. Averaging of Transmission Efficiency

DO-213 defined the average TE to be “of any continuous azimuth or elevation scan within the window area.” There were several conflicting interpretations of this definition among the members of the working group, confirming the need for more clarification. The radar manufacturers in the working group convened and decided the proper interpretation of that requirement from a radar perspective. The resulting clarification is illustrated in Figure 9 [3].

Figure 8. Radome SLL comparison to specs

Figure 9. DO-213A Figure 2-5 [3]

Figure 9 shows a grid of $n=5$ rows of constant elevation (radar scanning in azimuth) and $m=9$ columns of constant azimuth (radar scanning in elevation). DO-213A’s intended clarification on TE averaging is that $n+m=5+9=14$ averages are to be computed, and the smallest of those averages is to be compared against the specifications.

In preparing this paper, the authors noticed that DO-213A’s reference to its Figure 2-5 (copied here as Figure 9) got confused in one of the final DO-213A editing stages. There are two averaging operations when measuring TE. The first is an average of the power ratios at each of two quarter-wave slide positions, and this average is done separately at each aspect to attenuate any mutual coupling. The second averaging operation occurs after computing TE at each of the aspects, and this second average is the one illustrated by Figure 9 and described above.

IV. EXPECTED TRANSITION FROM DO-213 TO DO-213A

A commercial aircraft’s Component Maintenance Manual (CMM) typically begins by referencing DO-213, and then lists individual tests that need to be performed, sometimes exempting or expanding tests under certain conditions. The CMM, not DO-213, serves as the primary requirements document for testing a particular type of radome.

Given this hierarchy of requirements, it seems likely that DO-213A will become relevant when CMMs begin to reference it. It further seems likely, though NSI-MI has little visibility into the process, that DO-213A will be referenced starting with new aircraft models or perhaps significant changes in an existing aircraft’s radar or radome. Given current CMMs’ deviations from the specifics of DO-213, it will be interesting to see how closely new or updated CMMs track DO-213A.

V. CONCLUSIONS

DO-213 has been updated to DO-213A, with substantial NSI-MI inputs. This update has significant impacts on many after-repair radome-test facilities. One impact for the numerous facilities that use an el/az radome positioner is the clear statement that an el/az radome positioner is and was almost always inappropriate for either DO-213 or DO-213A testing. Impacts going forward for after-repair testing under DO-213A include the elimination of the conventional indoor far-field geometry as an allowable configuration and the new requirement for side-lobe testing at more aspects on a larger number of radomes.

REFERENCES