CT-TN
90/50

3

te technical note techn

Antenna Radome Sample Test Report

Leonard H. Baker
Thomas D. Bratton

January 1991

DOT/FAA/CT-TN90/50

Document is on file at the Technical Center
Library, Atlantic City International Airport, N.J. 08405

U.S. Department of Transportation
Federal Aviation Administration

Technical Center
Atlantic City International Airport, N.J. 08405

NOTICE

This document is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange. The United States Government assumes no liability for the contents or use thereof.

The United States Government does not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the objective of this report.

Technical Report Documentation Page

1. Report No. DOT/FAA/CT-TN/90/50	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle ANTENNA RADOME SAMPLE TEST REPORT		5. Report Date January 1991
		6. Performing Organization Code
7. Author(s) Leonard H. Baker, Thomas D. Bratton		8. Performing Organization Report No. DOT/FAA/CT-TN90/50
9. Performing Organization Name and Address Federal Aviation Administration Technical Center Atlantic City International Airport, New Jersey 08405		10. Work Unit No. (TRAIS)
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Technical Center Atlantic City International Airport, New Jersey 08405		13. Type of Report and Period Covered Technical Note
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

This test report documents the antenna radome sample test conducted at the Federal Aviation Administration (FAA) Technical Center by the Secondary Surveillance Systems Branch, ACN-220. The test configuration consisted of the antenna radome sample centered between the Discrete Address Beacon System's (DABS) antenna and its remote Calibration Performance Monitor Equipment (CPME). The Range and Azimuth Accuracy (RAA) diagnostic program was used to determine changes in DABS performance.

There were two test objectives. The first test objective was to determine if existing FAA en route radar antenna radomes would distort the signal characteristics detected by a beacon monopulse processor system. The second test objective was to determine whether this test configuration could be used to test radome samples supplied by prospective contractors in the en route radome replacement program.

The RAA diagnostic program could not determine if the radome sample depicted changes in the DABS performance.

It is recommended that this test procedure be abandoned due to inconclusive test results. The prospective radome manufacturers should provide the FAA with sufficient test data to confirm that it meets the requirements of the radome procurement specification.

17. Key Words Radome Sample Discrete Address Beacon System (DABS) Calibration Performance Monitoring Equipment (CPME) Range and Azimuth Accuracy (RAA)		18. Distribution Statement Document is on file at the Technical Center Library, Atlantic City International Airport, NJ 08405	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 16	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

TABLE OF CONTENTS

	Page
EXECUTIVE SUMMARY	v
1. BACKGROUND	1
2. OBJECTIVE	1
3. TEST CRITERIA	2
4. TEST METHOD	2
5. TEST RESULTS	4
6. CONCLUSIONS	7
7. RECOMMENDATIONS	9
APPENDIX	

LIST OF ILLUSTRATIONS

Figure		Page
1	Radome Sample Test Configuration	3
2	Antenna Azimuth Versus Test Position	8

LIST OF TABLES

Table		Page
1	Radome Sample Test Data	5
2	Baseline Test Data	6

EXECUTIVE SUMMARY

This test report documents the antenna radome sample test conducted at the Federal Aviation Administration (FAA) Technical Center by the Secondary Surveillance Systems Branch, ACN-220. It describes the radome sample test criteria, test method, and test results. The test configuration consisted of the antenna radome sample centered between a radar beacon antenna and a fixed ground transponder. There were two test objectives. The first test objective was to determine if existing FAA en route radar antenna radomes would distort the signal characteristics detected by a beacon monopulse processor system. The second test objective was to determine whether this test configuration could be used to test radome samples supplied by prospective contractors in the en route antenna radome replacement program.

An FAA CW-396 en route radome sample was used in the test configuration. The FAA Depot provided the radome sample previously used at an FAA en route radar/beacon facility. The available CW-396 sample is considered a worst case test criteria due to its thickness and steel assembly bolts.

The CW-396 test results provide the FAA with baseline data. This baseline data will be compared with data collected in the future on samples supplied by prospective radome manufacturers if required. It may be used during the source evaluation phase of the procurement.

The Discrete Address Beacon System (DABS) and its remote Calibration Performance Monitoring Equipment (CPME) was the test system. The DABS is the engineering model for the Mode Select System (Mode S); it is a beacon monopulse system. The DABS Range and Azimuth Accuracy (RAA) program was used to determine changes in DABS performance. The RAA is a DABS resident diagnostic program that operates with the CPME.

There were two areas where systematic uncertainties were detected in the Sample data analyzed. The first area was the constant shift in the antenna beam's leading edge. The second area was the consistent azimuth error results between the sample and baseline data. The consistent azimuth errors indicated minor discernible differences in the RMS azimuth errors and no discernible differences in the Mean azimuth errors. These two areas were unable to reveal if the sample configuration fully depicted antenna signal distortions.

It is recommended that this test procedure be abandoned due to the inconclusive test results. The prospective radome manufacturers should provide the FAA with sufficient test data to confirm that it meets the requirements of the radome procurement specification.

1. BACKGROUND.

The Federal Aviation Administration (FAA) is procuring 25 replacement antenna radomes for en route radar facilities. Each of these facilities is scheduled to receive a Mode Select System (Mode S). This system will replace the existing Air Traffic Control Radar Beacon System (ATCRBS). The National Airspace System (NAS) has placed stringent azimuth accuracy requirements on the new Mode S. The error budget allocated for the radome used with the Mode S is 0.044° of root mean squared (RMS) azimuth error. This is a primary requirement in the radome procurement specification. Various contractor radome samples may have to be tested prior to final source selection in the procurement process. Radome samples which exceed the error budget will not be considered for this procurement. Note, throughout this report, antenna radome sample will be referred to as "sample."

Preliminary antenna radome tests were conducted at the FAA Technical Center at the Atlantic City International Airport, N.J. The FAA Technical Center's Terminal Radar Beacon Test Facility (TRBTF) supported the actual test conduct. The purpose of the FAA's preliminary testing was to dry run the test configuration prior to actually testing radome samples supplied by manufacturers. The FAA would require bidders to supply radome samples for evaluation if the preliminary tests were a success.

The Discrete Address Beacon System (DABS) is located at the TRBTF. The DABS is a beacon monopulse system and was the engineering prototype for the Mode S. The DABS and its remote Calibration Performance Monitoring Equipment (CPME) were used to determine beacon monopulse system characteristics with and without the radome sample. The DABS Range and Azimuth Accuracy (RAA) diagnostic program was used to measure changes in beacon monopulse characteristics. This system test configuration, DABS/CPME/RAA, was used to determine the effects an actual antenna radome sample had on system performance.

All preliminary tests were conducted with a CW-396 sample. The sample was supplied by the FAA Depot; it is the same type used at the FAA en route radar/beacon facilities. It measured approximately 28 feet in length and 12 feet in height.

The sample was mounted on a special test platform. The platform was constructed from wood and built in two sections. The first section was a 47-foot tower erected close to the TRBTF Mode S/ASR-9 tower. The second section was a rectangular wooden base to which the radome sample would be mounted while on the ground. This second section would be set on the main tower by a crane and positioned at the desired test positions. The configuration placed the sample approximately 64 feet above ground level.

2. OBJECTIVE.

There were two test objectives. The first test objective was to determine if existing FAA CW-396 en route radar antenna radomes would distort the signal characteristics detected by a beacon monopulse system. The assumption was made that the CW-396 sample would be one of the worst test cases. Its material is of fiber-glass type, has a thick index of diffraction, and has steel assembly bolts. The second test objective was to determine whether this test configuration could accurately and reliably measure the effects different types of radome constructions

have on the performance of a monopulse system. Prospective radome manufacturers would provide the FAA with radome samples. The test configuration, if acceptable, would provide the FAA with quantitative data during the source evaluation phase of the en route antenna radome replacement procurement program.

3. TEST CRITERIA.

The Mode S system must be capable of interrogating and receiving replies from both ATCRBS and Mode S airborne transponders. The antenna radome must not degrade the Mode S system more than its allocated azimuth error budget. The error budget allocated for the radome used with the Mode S is 0.044° of RMS azimuth error.

The radome sample required for testing must completely shield a standard FAA 28-foot open planar array antenna. The sample must be sufficiently large so that the effect of the mechanism joining individual panels can be assessed. The capability to position the sample in discrete position between the open array antenna and the remote CPME must be provided. The distance between the sample and the open array antenna shall not exceed 20 feet.

Dynamic tests will provide data to characterize the monopulse open array antenna beam. Changes in beam width, boresight position, and changes in the beam's left and right edges will be determined. The Mean and RMS azimuth errors will be determined.

4. TEST METHOD.

The FAA Technical Center's TRBTF supported test conduct. The DABS and its associated remote CPME were used as the beacon monopulse system. The DABS RAA program was used to determine the system degradation introduced by the radome sample placed between the DABS open array antenna and the remote CPME. The RAA program collected data and provided statistical results. These results were used to determine system performance with and without the radome sample. Appendix A has operational information relative to the RAA diagnostic program.

The RAA program was run with and without the sample to determine that valid and repeatable data could be collected. The sample was repositioned laterally at numerous positions and the RAA program was run. The following details the actual test method.

There were 42 separate tests conducted. The RAA program collected data for each test. Tests 1 through 3 and tests 40 through 42 collected data without the sample. The sample was then positioned in 12 discrete locations on the test platform and data was collected. The RAA program was run three times and data was collected at each discrete position. This provided test data for tests 4 through 39.

Figure 1 is a pictorial representation of each test position. The sample was moved laterally at two different locations on the test platform. Measuring from the center of the open array antenna to the center of the sample; test positions 1 through 6 measured approximately 17 feet and test positions 7 through 12 measured approximately 11 feet. The distance between each lateral position was approximately 16 inches.

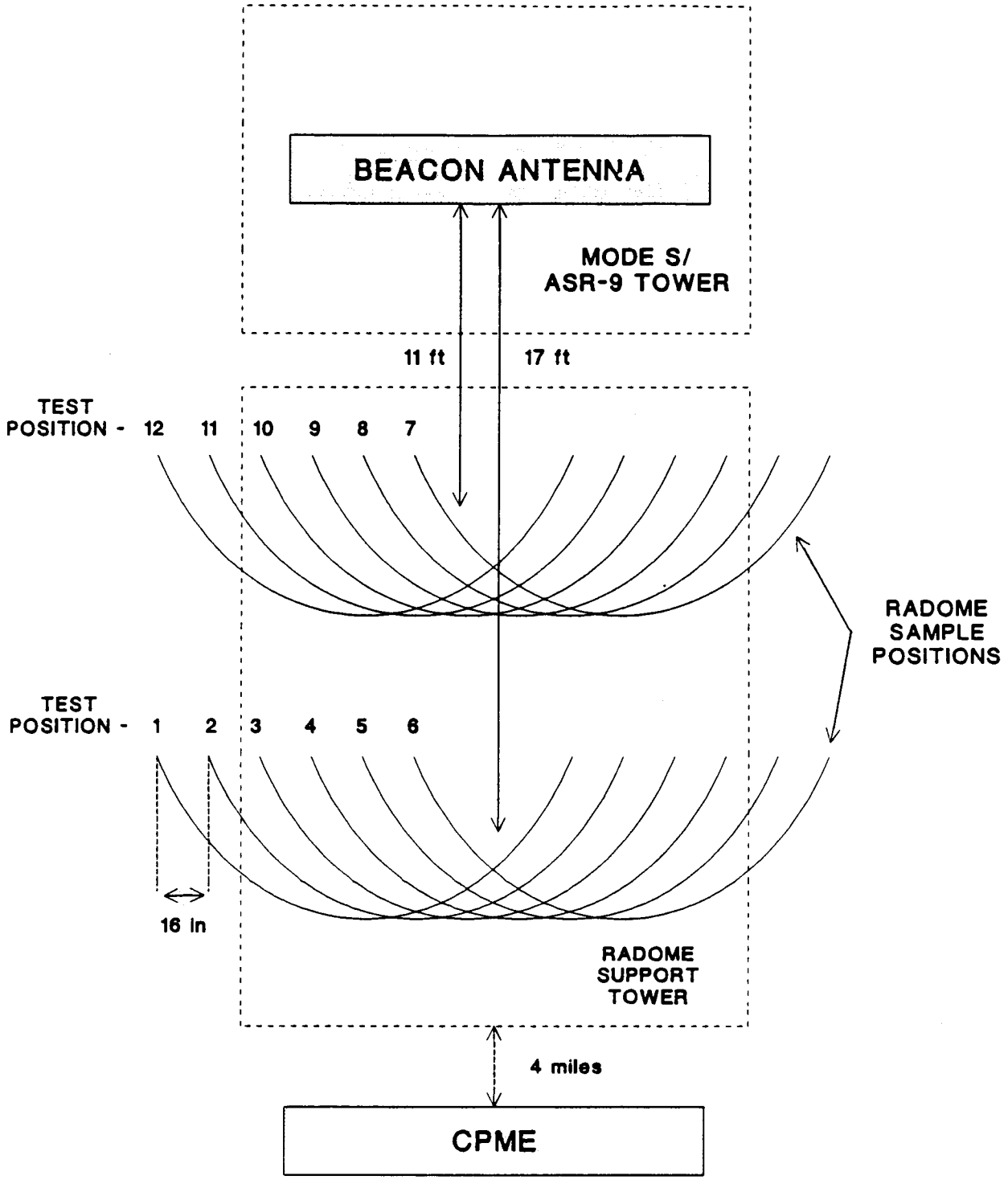

FIGURE 1. RADOME SAMPLE TEST CONFIGURATION

5. TEST RESULTS.

Tables 1 and 2 depict the DABS RAA test results. Tests were conducted with and without the antenna radome sample. The tables depict antenna beam positional data for: (1) left edge, (2) boresight, (3) right edge, and (4) antenna beam width. Beam width was calculated by obtaining the difference between the antenna right and left edges in azimuth units (au's). One au equals 0.02197°. The tables also include the RAA statistical results for Mean and RMS Azimuth Error. The Mean azimuth error was calculated by dividing the reply azimuth errors by the total number of replies. The RMS azimuth error was calculated by taking the squares of the reply azimuth errors, the mean of the squares, and the square root of the mean. All numerical values are in au's, measured from northmark with one exception; antenna beam width is measured in degrees.

Table 1 includes baseline test data with and without the radome sample conducted on May 31, 1990. Tests 1 through 3 and 40 through 43 depict baseline test data without the sample, and tests 4 through 39 depict test data with the sample.

Table 2 depicts RAA data collected without the test sample before and after the May 31, 1990, test conduct day. This baseline data is also used to supplement the baseline data in table 1.

The radome sample and baseline data will be compared to determine any significant azimuth error and beam width error differences. The following explains the analysis of the sample and baseline data comparison.

There were minor discernible differences in the RMS azimuth error data for tests conducted with the radome sample and tests conducted without the sample. Test 41 had the worst case RMS azimuth error without the sample; it was 3.0 au's. Test 14 had the worst case RMS azimuth error with the sample; it was 3.4 au's.

There were minor discernible differences in the test data when the radome sample was moved in different test positions. Tests 4 through 21, test positions 1 through 6, were conducted 17 feet away from the open array antenna. Tests 22 through 39, test positions 7 through 12, were conducted 11 feet away from the open array antenna. The average sample RMS error was 2.7 au's and 2.5 au's, respectively.

There were no discernible differences in the Mean azimuth error data for tests conducted with the sample and tests conducted without the sample.

There were minor discernible differences in the antenna beam width data for tests conducted with the sample and tests conducted without the sample. The collected antenna beam data indicate that the antenna beam width is narrowed slightly when the sample is in position. The tests conducted without the sample varied in beam width between 4.04° and 4.44° as shown in table 2. The average beam width without the sample in position was 4.30°. The beam width varied between 4.07° and 4.33° for tests conducted with the sample. The average beam width with the sample in position was 4.19°. The data indicated that the beam width decreased by 0.11° or 5 au's.

TABLE 1. RADOME SAMPLE TEST DATA

TERMINAL RADAR BEACON TEST FACILITY

	ANTENNA BEAM (AU's)			DEG.	AZIMUTH ERROR (AU's)		
TEST No.	LEFT EDGE	BORE-SIGHT	RIGHT EDGE	BEAM WIDTH	MEAN	RMS	TEST POSITION
1	962	868	765	4.33	.9	2.1	WITHOUT SAMPLE
2	962	868	767	4.29	.4	1.7	
3	959	869	766	4.25	.4	1.5	
4	961	869	769	4.22	-.6	2.3	1
5	958	870	769	4.16	0	1.9	
6	959	869	768	4.20	.3	2.4	
7	958	868	768	4.18	.1	2.3	2
8	958	869	769	4.16	0	1.9	
9	961	867	768	4.25	0	2.4	
10	960	869	770	4.18	0	2.9	3
11	960	870	771	4.16	.3	3.0	
12	960	869	771	4.16	0	2.9	
13	958	868	771	4.11	.1	3.0	4
14	959	868	771	4.14	.3	3.4	
15	959	868	773	4.09	0	3.1	
16	959	869	768	4.20	1.0	3.4	5
17	959	870	769	4.18	.4	2.6	
18	959	869	768	4.20	1.0	2.9	
19	958	868	765	4.25	1.2	2.8	6
20	957	868	765	4.22	1.0	2.7	
21	957	869	764	4.25	1.4	3.2	
22	959	868	765	4.27	1.4	2.5	7
23	959	868	762	4.33	1.0	2.2	
24	958	867	763	4.29	.8	2.4	
25	960	869	766	4.27	.8	1.9	8
26	959	868	766	4.25	.6	2.1	
27	960	869	766	4.27	.9	1.8	
28	961	870	771	4.18	-1.0	2.6	9
29	960	869	770	4.18	0	1.9	
30	960	869	773	4.11	-.6	2.8	
31	958	867	770	4.14	.5	2.8	10
32	960	869	772	4.14	0	2.6	
33	958	868	771	4.11	.2	2.1	
34	960	869	772	4.14	.4	3.1	11
35	960	869	769	4.20	.5	3.1	
36	956	868	771	4.07	-.1	2.5	
37	958	868	769	4.16	1.1	3.0	12
38	957	868	770	4.11	1.2	2.7	
39	959	868	769	4.18	.4	2.7	
40	957	868	765	4.22	.8	2.1	WITHOUT SAMPLE
41	962	869	765	4.33	.2	3.0	
42	961	868	764	4.33	.8	2.3	

TABLE 2. BASELINE TEST DATA

TERMINAL RADAR BEACON TEST FACILITY

	ANTENNA BEAM (AU's)			DEG.	AZIMUTH ERROR (AU's)		WITHOUT TEST SAMPLE
TEST No.	LEFT EDGE	BORE-SIGHT	RIGHT EDGE	BEAM WIDTH	MEAN	RMS	
5/01/90	959	869	769	4.18	0	2.4	
5/08/90	960	869	767	4.24	-.3	2.6	
5/07/90	951	871	767	4.04	-.7	1.9	
5/07/90	959	870	768	4.20	-.9	2.2	
5/11/90	964	869	763	4.42	-.2	1.4	
5/18/90	962	869	767	4.29	.3	2.0	
5/21/90	961	869	766	4.29	.2	2.1	
5/22/90	962	869	765	4.33	1.0	2.6	
5/22/90	961	869	767	4.26	.6	1.8	
5/23/90	962	868	765	4.33	.8	2.0	
5/25/90	960	869	765	4.29	.7	2.2	
5/25/90	963	868	766	4.33	.5	2.3	
5/30/90	964	868	762	4.44	1.0	2.1	
5/30/90	959	868	766	4.24	1.3	3.0	
5/30/90	962	869	764	4.35	.4	1.6	
6/06/90	964	869	766	4.35	0	2.4	
6/06/90	963	869	767	4.31	0	1.8	
6/06/90	963	869	765	4.35	.2	2.1	
6/07/90	962	868	766	4.31	.3	2.1	
6/07/90	963	869	765	4.35	.7	2.0	
6/07/90	964	868	766	4.35	.8	2.3	
6/07/90	961	868	766	4.29	.3	2.3	
6/08/90	962	869	766	4.31	.3	1.9	
6/08/90	962	870	768	4.26	0	2.1	
6/08/90	962	869	764	4.35	.8	2.5	

The test data indicated an azimuth shift in the right edge of the antenna beam when tested with the sample. This is the leading edge of the antenna beam when it comes into contact with the sample as it rotates in a clockwise direction. Test 15 was conducted with the sample. Its antenna beam right edge position value was 773 au's; the average baseline antenna beam right edge position value was 765 au's. The antenna beam right edge position had an 8.0 au bias; this equates to 0.176°.

Figure 2 depicts a graph of the antenna azimuth of each test position with the sample in place. The antenna azimuth values represent the left and right edges and boresight of the antenna beam. The solid and dashed lines, adjoining the data points, represent test positions 1-6 and 7-12, respectfully. The baseline data, obtained from tables 1 and 2, is also included at the base of the graph. The range values for the baseline data are shown as the blocked areas. The RAA diagnostic test was run three times for each test position. Therefore, the average azimuth values were plotted for each test position. The sample data for the boresight and left edge of the beam have data values within close proximity with its baseline data. The sample data for the right edge of the beam has data values offset up to 7 au's from its baseline data.

It could not be determined conclusively that the shift in the antenna right edge position would be present when there is a complete radome structure surrounding the antenna. The problem arose with the data collection tool used for analysis, the RAA diagnostic program. The RAA program goes through multiple calibration procedures before it is used as a diagnostic tool. The program builds both range and azimuth positional references and a reference monopulse table. Once this information is built and entered by the RAA program, it is used each time RAA is run. The calibration procedures and monopulse tables were generated without the presence of any radome sample. It is unclear what the results would be if the tests were repeated in the presence of a full radome, with the RAA calibration and monopulse lookup tables properly generated for that configuration.

6. CONCLUSIONS.

There were two areas where systematic uncertainties were detected in the sample data analyzed. The first area was the constant shift in the antenna beam's leading edge. This caused the antenna beam width to be narrowed. The second area was the consistent azimuth error results between the sample and baseline data. The consistent azimuth errors indicated minor discernible differences in the root mean square (RMS) azimuth errors and no discernible differences in the Mean azimuth errors. These two areas were unable to reveal if the sample configuration fully depicted antenna signal distortions.

The sample test data collected cannot further define the cause of the antenna beam's shift in its leading edge. It was unusual that only the leading edge of the antenna beam was constantly shifted and not the remainder of the beam. This was the case when the sample was tested both at 17 feet and 11 feet from the antenna. A shift in an antenna beam indicates a corresponding Calibration Performance Monitoring Equipment (CPME) azimuth offset error. The shift in the antenna beam's leading edge did not indicate a CPME azimuth offset error. It did not have a shift in the entire antenna beam. The cause of the antenna beam's shift in its leading edge was inconclusive.

There were no discernible differences in the antenna left edge and boresight positions.

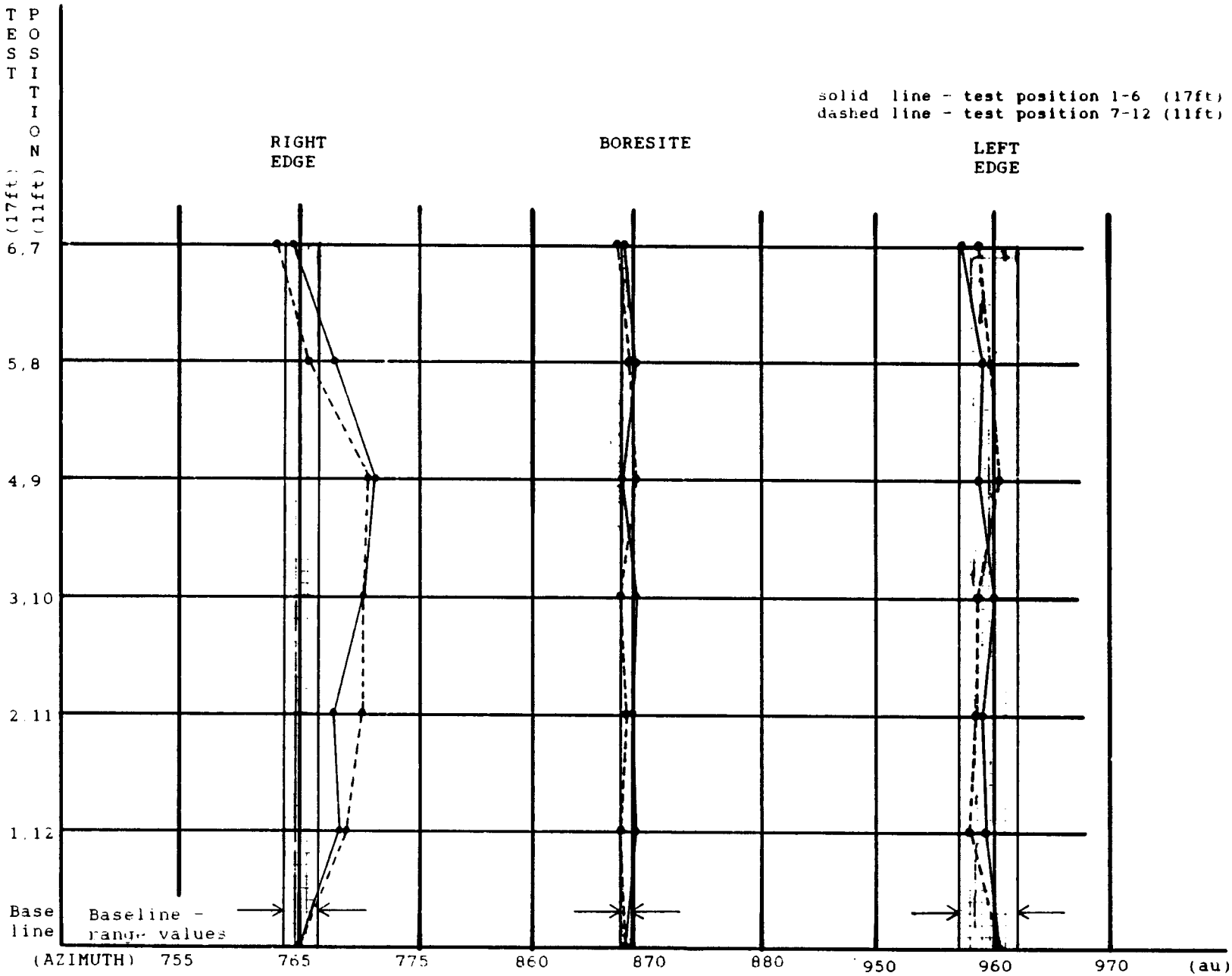

FIGURE 2. ANTENNA AZIMUTH VERSUS TEST POSITION

The sample test data did not repeat azimuth errors greater than the baseline data. It had antenna beam azimuth errors consistent with the baseline errors. The sample and baseline test data were within close proximity to each other. It was difficult to determine the differences of the sample and baseline test data.

The test configuration used for these tests does not support a conclusive analysis of the effects of the radome sample on beam edges or beam width.

The Range and Azimuth Accuracy (RAA) analysis program could not determine conclusively that the aberrations experienced during the sample tests would be present in a system which has a complete radome structure surrounding its antenna.

7. RECOMMENDATIONS.

It is recommended that this test procedure be abandoned. The results obtained appear to be inconclusive and cannot be easily substantiated by alternative engineering methods. It is recommended that the prospective radome manufacturers provide the Federal Aviation Administration (FAA) with sufficient test data to make the determination that their radome will not degrade Mode S performance, namely azimuth accuracy. The test data may be obtained using mathematical modeling techniques or measurements obtained at a calibrated antenna range.

APPENDIX A

DABS RAA Program Definition

The Range and Azimuth Accuracy (RAA) is a Discrete Address Beacon System (DABS) resident diagnostic program that operates with the Calibration Performance Monitoring Equipment (CPME). The RAA program examines the difference in phase of the received CPME signal as seen by each half of the monopulse open array antenna. This technique allows a precise determination of the angle between the target and the boresight (center) of the antenna. When the program executes, it builds a monopulse table in its processing section by repeatedly interrogating a fixed CPME. The CPME has been precisely surveyed for range and azimuth position. The RAA compares the known CPME position, the known orientation of the antenna, and the phase of the reply. The RAA program then develops a monopulse lookup table to provide a correction factor for the azimuth of replies based on their phase. The RAA program compares the existing monopulse lookup table with the monopulse values received during operation. It then provides a measure of the system RMS azimuth error.

When RAA is executed, bursts of Mode S rollcall interrogations are addressed to a specific CPME. The interrogations are generated at a 2000-pulse repetition frequency over a 6° azimuth wedge. CPME replies are collected by the DABS.

The RAA program provides a computer printout depicting the following for each CPME reply received: (1) an index number representing the interrogation number, (2) a failure code indicating whether a reply is good or bad, (3) a 32-bit reply message in Hex, (4) reply boresight azimuth, (5) reply monopulse, (6) reply monopulse corrected, (7) azimuth error, (8) reply range, and (9) corrected reply range. Antenna beam positional data for its left edge, boresight, and right edge can be derived from this data. The RAA program provides calculated statistical results for Mean and RMS Azimuth Error and Range. All numerical azimuth values are in azimuth units (au's) measured from northmark. All numerical range values are in two-way range units (ru's).