GENERAL DYNAMICS
SATCOM Technologies

STATIC LOAD & DEFLECTION TEST OF 1.2M SERIES 1120 ANTENNA SYSTEM

TR-430

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Revision 0

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Series 1120 Antenna System

1.0 Introduction and Purpose

This report documents the deflection test of the 1.2 meter, Series 1120 antenna system. The antenna system was tested using loads equivalent to wind speeds of 40 and 125 mph in the axial and yaw directions. Figure 3.1 depicts the Series 1120 antenna geometry.

2.0 Test Set-Up and Procedure

The antenna was constructed and mounted horizontally to the test fixture as shown in Figure 3.2. Four digital indicators were placed around the circumference of the antenna dish at the ends of the major and minor axes. A fifth indicator was placed below the mast pipe so that its contribution to the antennas deflection could be subtracted. The indicator positions are also shown in Figure 3.2. Figure 4.1.2 shows the antenna prior to loading. Additional images of the constructed antenna and test set-up can be found in Appendix A.

The axial and yaw tests were completed twice for improved accuracy. The appropriate load was applied to the center of the dish to simulate the axial force for each of the test wind speeds. The yaw moment experienced around the mast pipe was tested by applying the 40 mph load 12 inches from the center of the dish (See Figure 3.2). Figure 3.3 illustrates the positive sign convention used in these tests and contains force and moment nomenclature.

All digital indicators were zeroed before each test. The load was applied to the reflector and the indicator displacements were recorded. This method was followed for each load case in Tests A and B. The deflection data can be found in Table 3.1 and the detailed calculations for the antennas rotation in the azimuth and elevation directions can be found in Appendix B.

3.0 Summary of Results

The deflections from the two tests were averaged to provide more accurate results. The series 1120 antenna yielded a beam pointing error of 0.0735º under a 40 mph axial load that resulted in a 0.04 mid-band dB loss at 14.25 GHz. A beam pointing error of 0.4849º under a 40 mph yaw load yields a 1.87 mid-band dB loss at 14.25 GHz. Scaled pointing errors and dB losses for 30 and 50 mph can be found in Table 4.4.1

Survival of the series 1120 antenna depends upon the winds attack angle and speed. The 1120 series can survive wind speeds up to 125 mph within an attack angle range of 0º to 55º. Within the wind attack range of 55º to 120º, the survival wind speed reduces to 86 mph where rotation around the mast pipe will occur. No permanent structural damage was observed for either test case. Re-pointing will be required if the antenna weathers a wind speed of 8 mph at 120º.

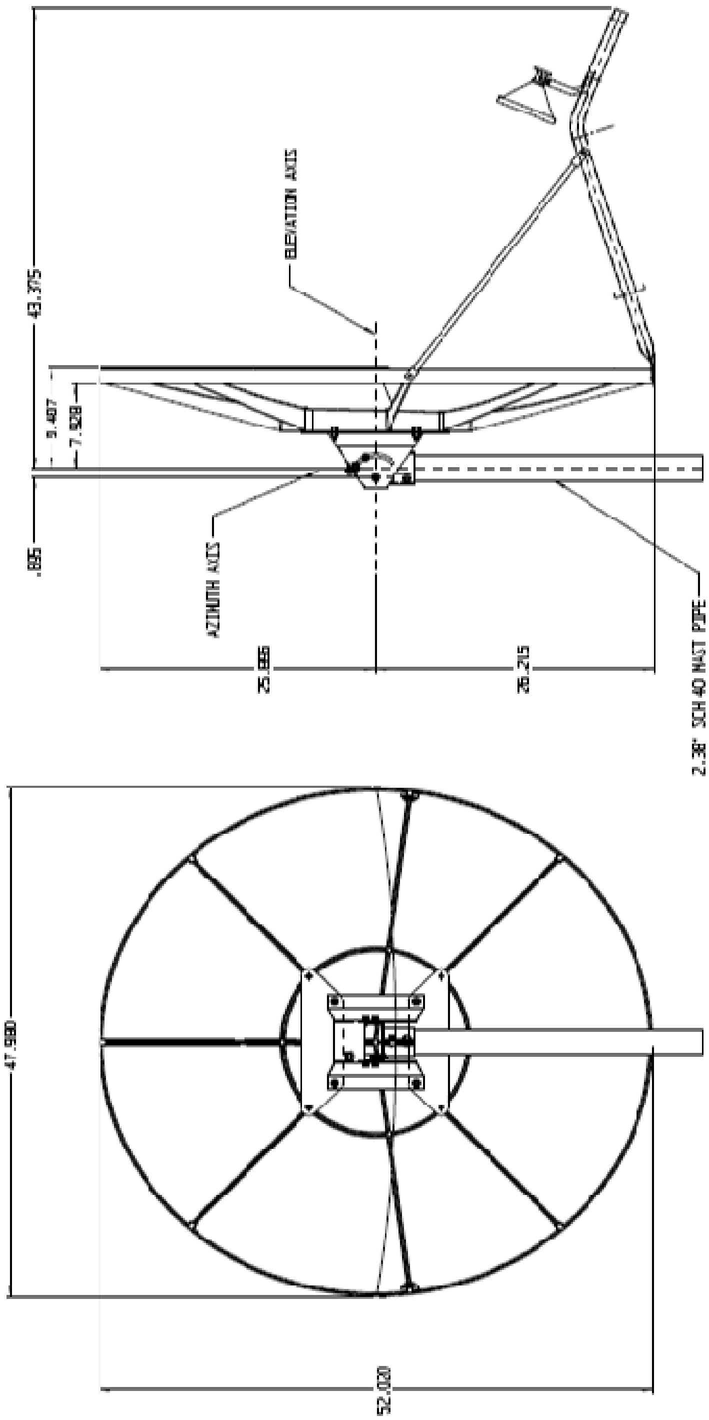


Figure 3.1 Antenna Geometry

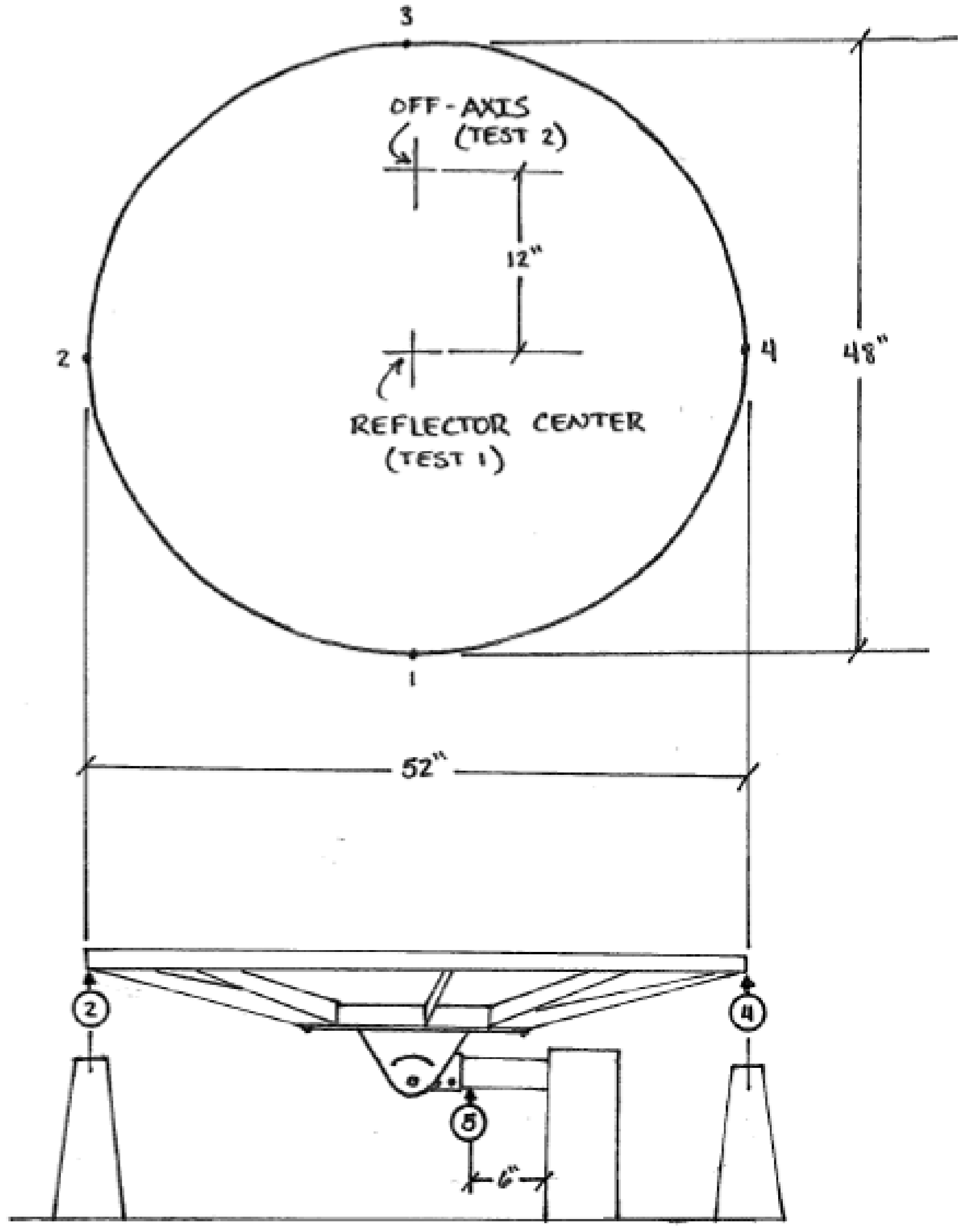


Figure 3.2 Test Set-Up

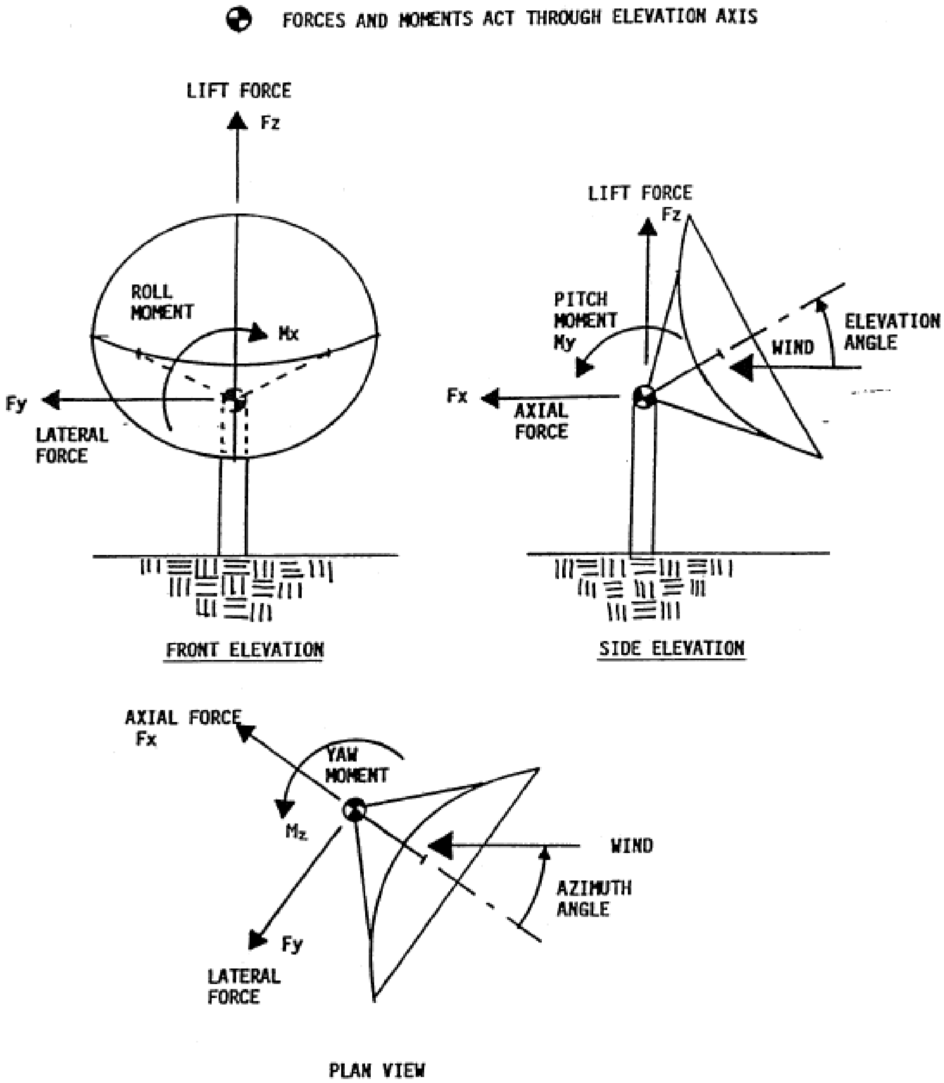


Figure 3.3 Report Nomenclature

Table 3.1 Test A & B Deflection Data

Test	Wind Speed (mph)	Direction	Digital Indicator (inch)				
			1	2	3	4	5
A	40	Axial	-0.0570	-0.0220	0.0005	-0.0160	0.0010
		Yaw	0.1685	-0.0025	-0.2525	0.0290	0.0020
B	40	Axial	-0.0560	-0.0455	0.0055	0.0095	0.0035
		Yaw	0.1595	-0.0040	-0.2315	0.0205	0.0010

4.0 Analysis

4.1 Wind Loads

Wind loads are determined by the JPL Computer Program. JPL determines wind forces and moments based upon wind speed, wind direction, dish size, and antenna geometry. The antenna geometry includes the axial, vertical, and lateral offset distances from the mast pipe centerline. Figure 4.1.1 shows the JPL output for the Series 1120 antenna.

[Inactive WIND_2.EXE]

Series 1120 Analysis by 06-08-2010 08:13:02
Wind Speed 40.0 mph Dish Size 1.2 meters Axial Offset 0.5 feet
Vert Offset 0.0 feet Lat Offset 0.0 feet
All values shown below are maximum absolute values

angles		forces (lbs.)			moments (ft. lbs.)		
el	az	fx	fy	fz	mx	my	mz
		axial	lateral	lift	roll	pitch	yaw
0	55	82					
0	120		11				
60	0			71			
90	90				29		
60	180					32	
0	120						32

[Inactive WIND_2.EXE]

Series 1120 Analysis by 06-08-2010 08:16:34
Wind Speed 125.0 mph Dish Size 1.2 meters Axial Offset 0.5 feet
Vert Offset 0.0 feet Lat Offset 0.0 feet
All values shown below are maximum absolute values

angles		forces (lbs.)			moments (ft. lbs.)		
el	az	fx	fy	fz	mx	my	mz
		axial	lateral	lift	roll	pitch	yaw
0	55	797					
0	120		104				
60	0			689			
90	90				285		
60	180					311	
0	120						311

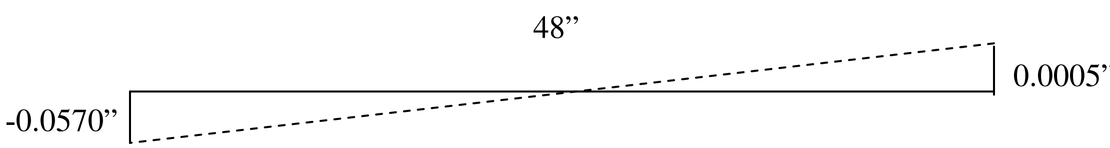
Figure 4.1.1 JPL Output

The maximum axial force is achieved when the wind is attacking the antenna reflector from an elevation of 0º and a 55º azimuth direction. Through SATCOM's wind tunnel testing of parabolic antennas, the drag coefficient is highest at these two angles (El: 0º, Az: 55º). For the 40 mph axial case, 82 lbs was loaded at the reflectors center, and 32 lbs was loaded 12 inches off-center for the yaw case. 797 lbs was axially loaded to simulate a survival wind speed of 125 mph. The fully constructed antenna is shown below in Figure 4.1.2 with the digital indicators placed around the dishes circumference and below the mast pipe.

Figure 4.1.2 Series 1120 Test Set-Up

4.2 Beam Pointing Error

The deflection of the antenna is reduced to angles of rotation along the elevation and azimuth axes. These rotations are determined by dividing the net deflection by the distance between the points along the axis, and finding the corresponding angle. This calculation can be seen below for Test A's axial azimuth angle, with detailed angle calculations located in Appendix B.



$$\theta_A = \tan^{-1}\left[\frac{|-0.0570-0.0005|}{48}\right] = 0.0686^\circ \qquad \textit{Equation 4.2.1}$$

For the elevation axis, the rotation of the mast pipe is subtracted from the rotation of the dish. This serves as a correction factor for the elevation rotation so that the vector sum between the two rotations can be found.

For Test A's axial case the elevation rotation was -0.0029º and the azimuth rotation was 0.0686º. The vector sum of the two rotations is:

$$(0.0686^2 + (-0.0029)^2)^{1/2} = 0.0687^\circ \qquad \textit{Equation 4.2.2}$$

An excel spreadsheet was used to compute all of the elevation and axial angles, and to average the pointing error between tests A and B. Detailed calculations that the excel sheet uses can be found in Appendix B for Test A's axial directions. The calculated angles can be seen in Table 4.2.1.

Table 4.2.1 Pointing Error

Test	Wind Speed (mph)	Direction	**Pointing Error Calculations (º)**									
			Elevation Error		Fixture Rotation		Net Elevation Error		Azimuth Error		**Pointing Error**	
A	40	Axial	θ_D	0.0066	θ_T	0.0095	θ_E	-0.0029	θ_A	0.0686	θ	0.0687
		Yaw	θ_D	0.0347	θ_T	0.0191	θ_E	0.0156	θ_A	0.5025	θ	0.5028
B	40	Axial	θ_D	0.0606	θ_T	0.0334	θ_E	0.0272	θ_A	0.0734	θ	0.0783
		Yaw	θ_D	0.0270	θ_T	0.0095	θ_E	0.0174	θ_A	0.4667	θ	0.4670
Average		Axial	θ_D	0.0336	θ_T	0.0215	θ_E	0.0121	θ_A	0.0710	θ_{AX}	**0.0735**
		Yaw	θ_D	0.0309	θ_T	0.0143	θ_E	0.0165	θ_A	0.4846	θ_{YAW}	**0.4849**

4.3 Wind Speed Scaling

Static load testing was performed for a steady state wind speed of 90 mph. Assuming there is a linear relationship between the wind load and angle of rotation, rotations for various wind speeds can be computed. There is an exponential relationship between wind speed and its corresponding static load as seen in Equation 4.3.1.

$$F = 0.00256 * V^2 * C_A * A \qquad \textit{Equation 4.3.1}$$

Where F is the load in pounds, V is the wind speed in mph, C_A is the drag coefficient, and A is the reflector area in ft^2. The averaged axial and yaw angles for 40 mph were scaled to 30 and 50 mph. This was done by multiplying the the 40 mph angle by a correction factor of $(30/40)^2$ for the 30 mph case. The scaled angles can be found below in Table 4.3.1.

Table 4.3.1 Scaled Angles

Scaled Angles		
Direction	Speed (mph)	Beam Pointing Error (º)
Axial	30	0.0413
	40	0.0735
	50	0.1148
Yaw	30	0.2728
	40	0.4849
	50	0.7577

4.4 dB Loss

The dB losses from peak gain were computed by a Radio Frequency (RF) Engineer for the calculated and scaled angles. The dB losses can be found below in Table 4.4.1

Table 4.4.1 dB Loss

dB Loss from Peak Gain			
Direction	Speed (mph)	Beam Pointing Error (º)	dB Loss @ 14.25 GHz
Axial	30	0.0413	0.02
	40	0.0735	0.04
	50	0.1148	0.10
Yaw	30	0.2728	0.59
	40	0.4849	1.87
	50	0.7577	4.57

4.5 Survival Wind Speeds

The Series 1120 antenna survived a 125 mph axial wind load with out failing. Figure 4.5.1 depicts the 797 lb survival wind load placed on the reflector. The reflector and mount did not sustain any permanent deformation.

Figure 4.5.1 Survival Wind Load

The antenna was also able to withstand an 86 mph equivalent yaw load of 147 lbs. before the antenna slipped around the mast pipe. The antenna was able to be re-pointed since it only rotated around the mast pipe and did not sustain any structural deformations while under the load.

5.0 References

Prodelin Technical Report TR101 “Wind Design Loads for VSAT Antennas”, 1988.

Jet Propulsion Laboratories (JCL) Internal Memorandum JCL CP-3, “Preliminary Report on Paraboloidal Reflector Antenna Wind Tunnel Tests” Feb 1962.

Appendix A Additional Images

Image A.1 Side View

Image A.2 Yaw Load

Image A.3 Axial Load

Image A.4 Mast Pipe Indicator

Image A.5 Digital Indicator 1

Image A.4 Az/El Mount

Appendix B Detailed Calculations

TEST A - Axial Loading - 40 mph - 82 lb

- ELEVATION POINTING ERROR

$$\theta_D = \tan^{-1}\left[\frac{|-0.0220-(-0.0160)|}{52}\right] = 0.0066°$$

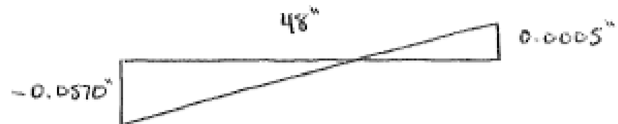
- TEST FIXTURE ROTATION

$$\theta_T = \tan^{-1}\left(0.0010/6\right) = 0.0095°$$

- NET ANTENNA ROTATION

$$\theta_E = \theta_D - \theta_T = \underline{-0.0029°}$$

- AZIMUTH POINTING ERROR



$$\theta_A = \tan^{-1}\left[\frac{|-0.0570-0.0005|}{48}\right] = \underline{0.0686°}$$

- VECTOR SUM

$$\theta = \sqrt{0.0686^2 + (-0.0029)^2}$$

$$\theta = 0.0687°$$