STRUCTURAL RESPONSE OF THE SATCOM ANTENNA TO A BLAST LOADING

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ABSTRACT

The accuracy of the ADINA finite element program in modeling the transient response of a dish shaped antenna has been evaluated. Computed strain histories were compared with strain gage records from a simulated nuclear blast test performed on the antenna. With an 839 degrees-of-freedom finite element model, the program reproduced the salient features of the response, although a close correspondence between computed and test results was not realized. The study, however, did demonstrate that the model is sufficiently accurate for survivability estimates.

I. INTRODUCTION

A shock tube test simulating a nominal 2.5 psi nuclear blast was performed on the SATCOM antenna and strain gage records were collected. The corresponding pressure loading was determined in a series of tests on a scale model of the antenna's reflector. The loading data were used in the ADINA finite element model of the antenna to calculate the strain histories at the gage locations. The accuracy of the finite element model was evaluated by comparing the computed strain histories with the strain gage records.

II. SATCOM ANTENNA

The SATCOM antenna is a component of the AN-GSC-86 satellite communication ground terminal developed by the U. S. Army Satellite Communication Agency (SATCOM). The antenna consists of a dish shaped reflector connected at the back to the tracking mechanism which is supported by a quadrupedal truss assembly. The reflector itself comprises a 1.22 m (4 ft) diameter center section to which the tracking assembly attaches, and four identical petal sections that attach to the periphery of the center section and to each other to form a rigid, paraboloidal dish 2.44 m (8 ft) in diameter. Figure 1 illustrates this arrangement and also indicates schematically the monocoque construction of the reflector, consisting of front and rear skins which attach every 15° to radial ribs, with circumferential rings capping the component sections along their common interface.

III. SHOCK TUBE TESTS

Two series of tests were performed at the shock tube facility. In the first series a sample of the actual antenna was exposed to a series of progressively larger blast waves emanating from the open end of the BRL 2.44 m (8 ft) diameter shock tube (1). The antenna was mounted facing the

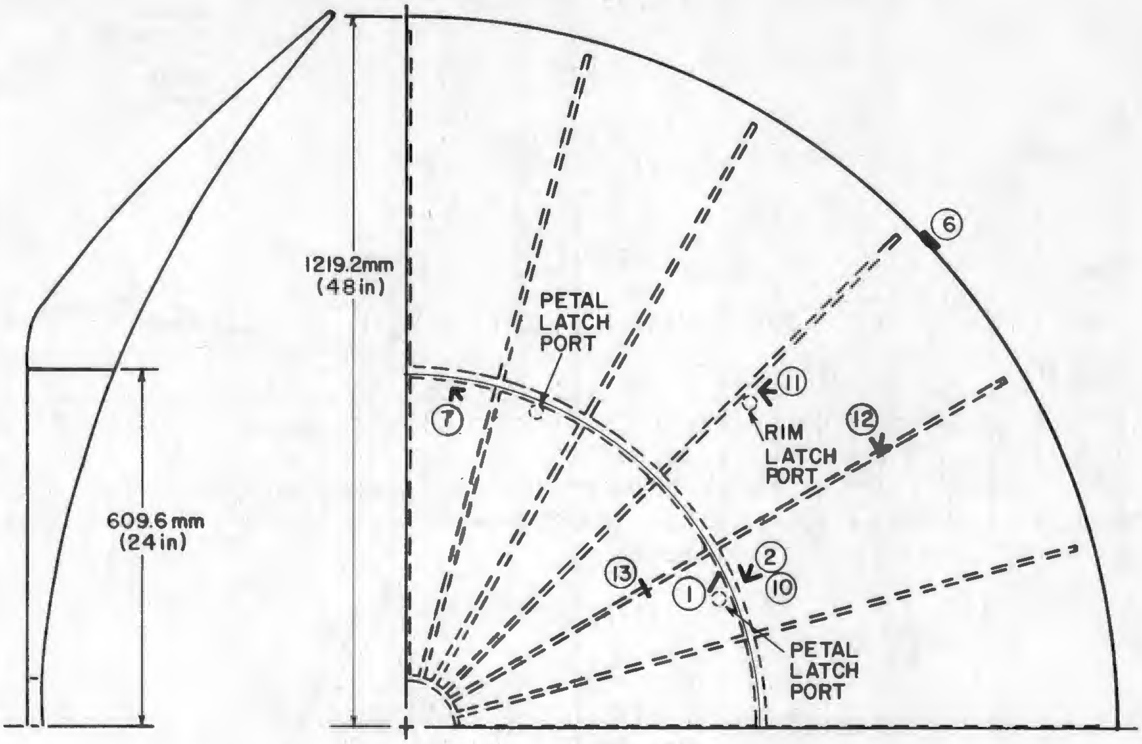
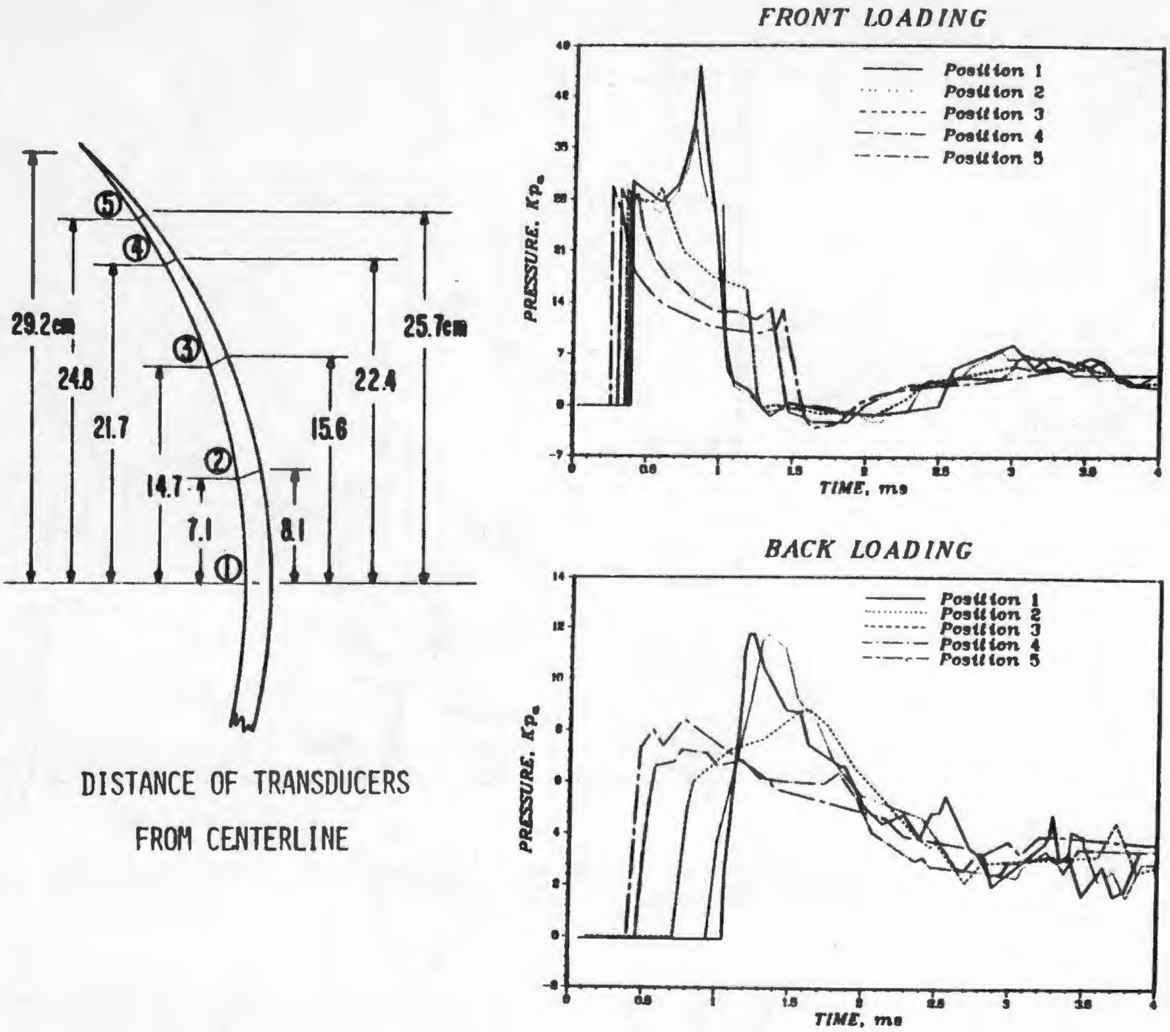


Figure 1. Front view of the upper-right quadrant and cross-section of the SATCOM antenna reflector.

open end along a line 24° to the side of the tube axis. Strain gages were cemented to the skin of the reflector at locations 1, 2, 6, 7, 10, 11, 12, 13 in the upper-right quadrant as indicated in Figure 1. The strain records chosen for comparison were from the last test of the series, in which the antenna at a distance of 12.2 m (40 ft) from the open end was exposed to a 17.2 kPa (2.5 psi) free-field blast.

The second series of tests was performed on a scale model of the reflector at a corresponding location outside the BRL 0.575 m (22.6 in) diameter shock tube (2). The purpose was to determine the loading function for the finite element analysis from pressure measurements on the model. The model was scaled in proportion to the ratio of the shock tube diameters (0.575/2.44 = .236). A row of pressure transducers was imbedded along a radius flush with the front and rear faces, as illustrated in Figure 2.

The model was located at a scaled distance of 2.87 m (9.4 ft) from the open end of the shock tube and subjected to a free-field pressure of 13.8 kPa (2.0 psi) in a series of tests in which the row of transducers was rotated by increments of 45°. It was found that the pressure distribution varied little with angle, so that the profiles along the vertical radius depicted in Figure 2 typify those found along the other radial directions. This result made it convenient to use an axisymmetric loading function obtained by circumferentially averaging the experimental pressure data.



DISTANCE OF TRANSDUCERS FROM CENTERLINE

Figure 2. Location of transducers on scale model and corresponding pressure records along a vertical radius.

Of the elements available in the ADINA finite element program (3), the three-dimensional plane stress element was chosen as the most suitable for modeling the sheet metal construction of the reflector. Use of an axisymmetric loading function allowed us to take advantage of the two planes of structural symmetry of the reflector to model only one quadrant, as illustrated in Figure 3. The rim and petal latchings were simulated by having the reflector components share common nodes at their points of attachment. Assumimg that the tracking and support assembly was rigid compared to the reflector, the nodes at the points of attachments to this assembly were fixed. Except at the common nodes connecting the petals to the center section, the elements employed 4 nodes. This resulted in the reflector being modeled by a total of 342 elements, using 306 nodes with 839 degrees-of-freedom.

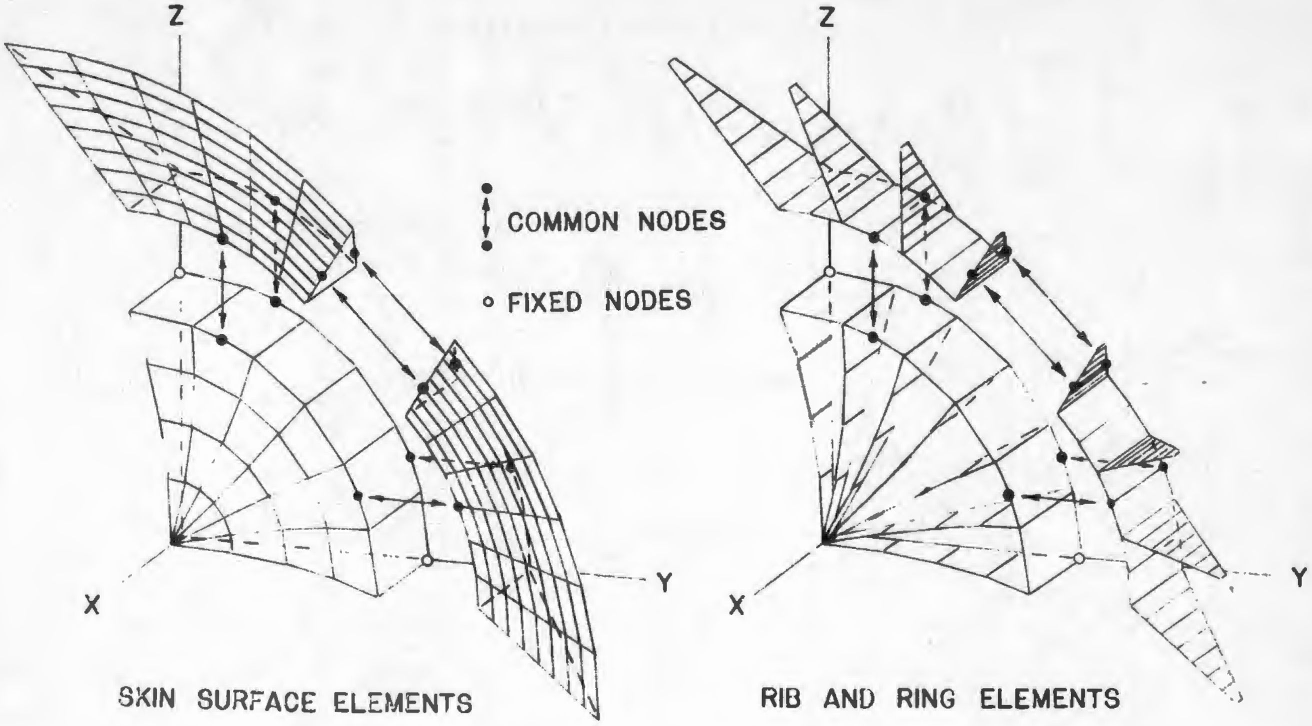


Figure 3. Exploded views of the finite element model of the upper-right quadrant of the reflector.

Since the recorded strains were well within the elastic limit, a linear analysis sufficed. Hence, only the elastic constants for the aluminum,

Young's Modulus = 68.95 GPa (10^7 psi) & Poisson's Ratio = 0.3

had to be specified. The thickness of the center section elements was taken as 1.613 mm (0.0635 in) and the petal elements as 1.359 mm (0.0535 in), and the density was set equal to 2768 Kg/m^3.

In addition to the loading data being circumferentially averaged, as already mentioned, these data were extended by interpolation over the entire surface of the reflector to provide full-field pressure histories for the analysis. Moreover, the pressure levels had to be proportionally scaled from the nominal 13.8 kPa of the model tests to the 17.2 kPa of the full-scale test, and the time scale had to be expanded by a factor of 1/.236 to account for the difference in loading times between the model and the antenna. Also, since the expansion only provided data for the first 16 ms, while it was intended to compare strains over the first 50 ms, the last recorded values of the pressures were maintained constant till the end.

The long duration of 50 ms made it advisable to choose the Newmark implicit time integration method. Employing the default values of the Newmark parameters (a = 1/4 and w = 1/2), the calculation was carried out for a total of 50 cycles using a time step of 1.0 ms, and the strain histories at points corresponding to the gage locations were computed.

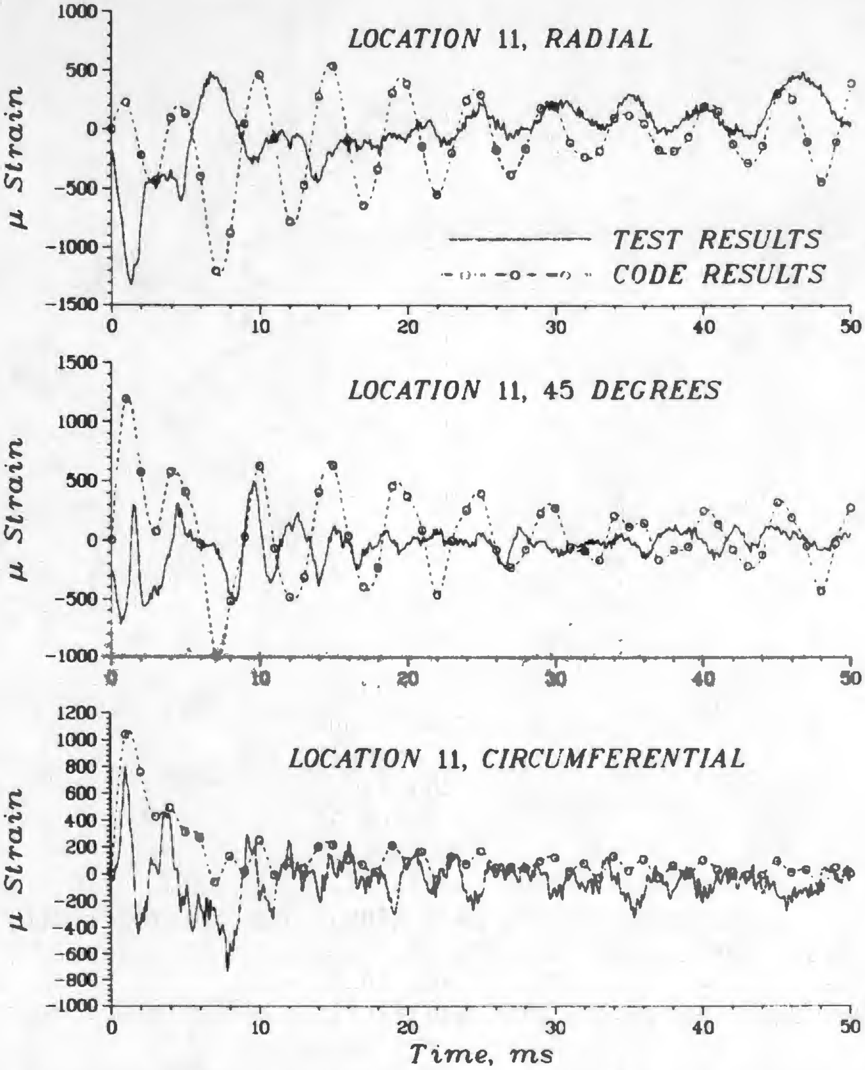


Figure 4. Comparison of computed and recorded strain histories at strain rosette location 11.

V. COMPARISON OF RESULTS

We focus on a comparison with the three strain histories recorded by the rosette at strain location 11 (see Figure 1). The degree of correlation, as shown in Figure 4, is typical of that achieved at the other locations, in that the computed results more-or-less capture the prominent features of test results, although the details, especially near the beginning, are missed. By comparing periods and ranges of amplitude in the table below, we see that correspondence is closest in the radial and circumferential directions and somewhat poorer at 45°.

In general, it was found that computed and experimentally determined amplitudes and frequencies at all gage locations were of the same order, although the curves did not agree very closely over the entire interval. Nonetheless, the correlation is surprisingly good when we consider, in addition

Gage Direction	Period (ms)		Range of Amplitude (microstrain)	
	Test	ADINA	Test	ADINA
Radial	5	5	-1350 + 500	-1210 + 537
45^o	2.6	5	- 730 + 500	-1000 +1190
Circumferential	2.7	2.1	- 750 + 800	- 98 +1040

to the modest size of the finite element model and the aforementioned simplifications, the structural details that were unaccounted for and the uncertainty in the loading function. For example, no attempt was made to reproduce the details of the latching mechanisms. Moreover, the analysis completly neglected the contact interactions at component interfaces. As for the loading data, unaccountable discrepancies between the free-field records from the full-size and model tests (1, 2) suggest that significantly different loadings were experienced by the reflector and the model.

In summary, the comparison does show that even with a fairly crude representation of the antenna, the ADINA finite element model reproduced the salient features of the response. The study certainly demonstrated the adequacy of ADINA model in determining survivability, confirming that the antenna is capable of surviving a 17.2 kPa blast.

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