Construction and Evaluation of a Lightweight Parabolic Antenna Model

D. L. Pope,* W. H. Hewitt Jr.,† and J. G. Tetz‡
Bell Telephone Laboratories, Inc., Whippany, N.J.

Theme

A CONCEPT for a large, lightweight, parabolic antenna which relies on the equilibrium of internal forces to achieve dimensional stability has been realized in a model 10 ft in diameter weighing only 1.7 lb. The model was constructed to verify the feasibility of the structural concept and to determine the gross features of the electrical performance.

Contents

The structure consists of a central mast, a torus, three tension wire systems, and a fine wire mesh to form the reflecting surface. The two compression members, the mast and torus, are interconnected by a guy wire system which establishes the plane of the torus and stabilizes the mast against buckling. Wires located in the plane of the torus to form a grid of equilateral triangles constitute the facet wire system. The nodes of the facet wire system are attached to the rear portion of the mast by 163 tension elements of the tie-back wire system. The facet wire system and connection pattern for facet wire nodes is shown in Fig. 1. The tie-back wires are adjusted to produce a controlled deformation of the triangular grid. The paraboloidal surface is approximated by 294 plane equilateral triangles, or facets. The facets are filled with a fine wire mesh. Figure 2 shows the guy wire and tie-back wire systems in a side view of the antenna concept.

The torus is 10 ft in diameter and the central mast is 12 ft long. These two members are composed of various lengths of inflated (8–10 psi), 0.001 in. Mylar 1 in. tubing. The question of the integrity of the Mylar compression members in a meteoroid environment is dealt with in Ref. 1. Special fittings are required at the junctions of the inflated Mylar tubes to transmit forces from the tension wire systems and to maintain pressurization. These fittings alone comprise 34% of the weight of the model. Five mil beryllium-copper wire is used throughout for tension wires. Approximately 2400 ft of wire, contributing 12% of the weight, is used in the model. The reflecting surface is formed from 0.003 in. beryllium-copper expanded metal mesh with $\frac{1}{8}$ in. × $\frac{1}{4}$ in. diamond-shaped openings. The effective reflecting area is equivalent to a paraboloid 8.4 ft in diameter. The reflecting surface contributes 43% of the total weight. The remaining weight is associated with the Mylar tubes, (5%), and the feedhorn, waveguide and pressure seal, (6%).

The model was constructed using a commercial aluminum reflector 10 ft in diameter with $f/D = 0.5$ as a form. The expanded metal mesh facets of the reflecting surface were attached to the facet wire system by beryllium-copper ties. Otherwise, the construction was relatively straightforward. Careful adjustment of the tensions in the guy wire and tie-back wire systems was required to achieve the proper reflecting surface geometry. A template was used to check

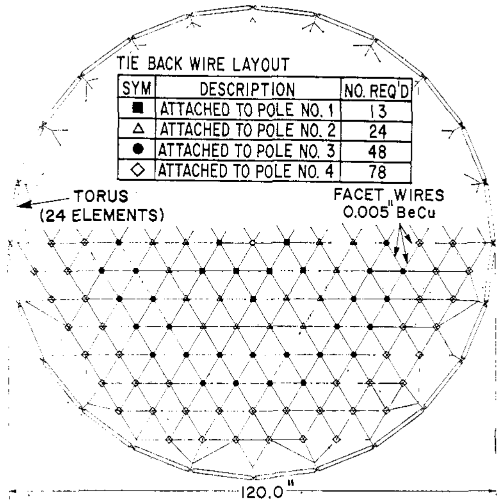

Fig. 1 Plan of antenna concept showing facet wire system and mode connections.

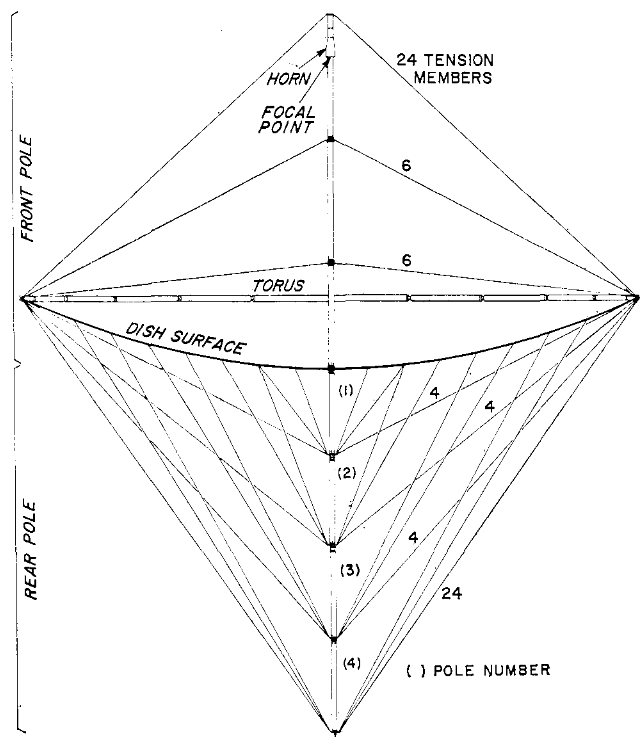

Fig. 2 Elevation of antenna concept showing guy wire and tie-back wire systems.

Presented as Paper 71-397 at the AAS-AIAA Variable Geometry and Expandable Structures Conference, Anaheim, Calif., April 21–23, 1971; submitted April 28, 1971; synoptic received July 6, 1971; revision received December 29, 1971. Full paper is available from AIAA. Price: AIAA members, $1.50, nonmembers, $2.00. Microfiche, $1.00. **Order must be accompanied by remittance.**

Index categories: Unmanned Earth Satellite Systems; Spacecraft Configuration and Structural Design.

* Supervisor.

† Member of Technical Staff.

‡ Senior Technical Aide.

the shape of the reflector. Final adjustment was an extremely tedious and delicate procedure.

Electrical performance of the model reflector was determined in the 8–12 GHz frequency band. A special fixture was required to support the model for these tests. The antenna provides a maximum gain of 39 db at 9 GHz, with a 3 db beamwidth of 0.9° and first sidelobes 13 db down. The results of these measurements are represented by curve A of Fig. 3. A perfect 8.4 ft paraboloid would produce slightly more than 46 db gain at 9 GHz. The 7 db difference between the performance of the model and an ideal reflector is attributable largely to two factors: 1) the porosity of the reflecting surface, and, 2) the deviations of the reflecting surface from a paraboloid. The rms surface tolerance of the antenna model was determined, using Ruze's approximation[2] for the on-axis gain, to be 0.104 in.

Aluminum facets, the same size as the expanded metal mesh facets of the model, were mounted on the concave face of the 10 ft aluminum paraboloid to duplicate the facet pattern of the model. The electrical performance of this configuration is indicated by Curve B of Fig. 3. The rms surface tolerance of this reflector was 0.054 in. There is, of course, no loss due to surface porosity. Curve C represents the performance of an ideal 8.4 ft paraboloid. The difference between Curve B and Curve C indicates the gain performance degradation associated with the facet pattern. Curve D gives the theoretical performance of an antenna with an rms surface tolerance of 0.104 in., but with no loss due to porosity. Comparison of the gain performance indicated by Curves A, B and D isolates the degradation associated with the increase of surface variations and the decrease of surface reflectivity in the model antenna.

The expanded metal mesh facet material is unsatisfactory. Although adequate electrically, it is relatively stiff and difficult to form accurately. Surface variations in individual facets contribute a significant portion of the total rms surface tolerance for the model antenna. A better method to obtain the necessary reflecting surface properties is required.

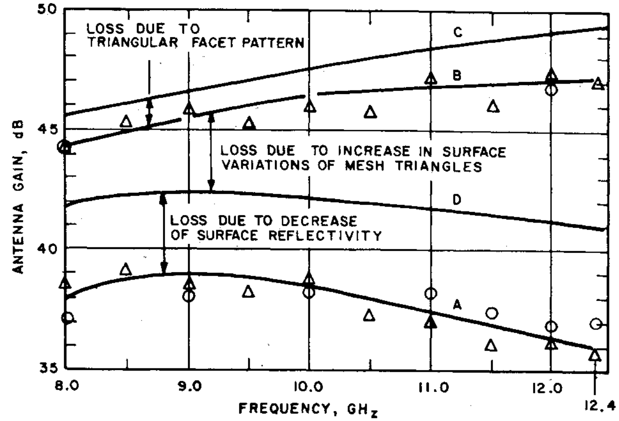

Fig. 3 Gain performance comparisons.

The major questions of deployment, dynamic response and the effects of solar radiation on this configuration have not been considered. These points require careful investigation before the practicality of this concept can be fully determined. The feasibility of the structural approach has been verified, however, and an acceptable radiation pattern and gain performance have been demonstrated. An improved reflecting surface and refinement of the structural design should result in further gain improvement of as much as 4 db with only a modest increase in total antenna weight.

References

[1] D. L. Pope, "A Meteor Shield Effectiveness Analysis," *Journal of Spacecraft and Rockets*, Vol. 4, No. 11, Nov. 1967, pp. 1559–1562.

[2] J. Ruze, "Antenna Tolerance Theory—A Review," *Proceedings of the IEEE*, Vol. 54, No. 4, April 1966, pp. 633–640.