THE TENSION TRUSS ANTENNA CONCEPT

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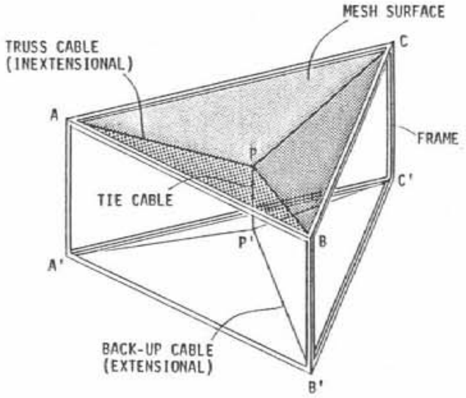
1. CONCEPT OF TENSION TRUSS ANTENNA

As a short introduction to the concept of the tension truss antenna, let's consider a simple structure consisting of a cable assembly as shown in Fig. 1. In this figure, ABCC'B'A' is a rigid frame, AP,BP,CP are inextensional truss cables, A'P',B'P',C'P' are extensional back-up cables, and PP' is a tie cable. Here, the term "inextensional" is used in a sense that the inextensional cable has much higher extensional rigidity than the extensional one. Then, if every truss cables are maintained at least in the state of tension, no matter how much the quantity is, the position of the node P is uniquely determined by the length of truss cables and is independent of the amount of forces within the cable assembly; while the position of node P' is determined by the equilibrium of forces. The strains in truss cables are so small that there is almost no effect on the position of P. Therefore, the mesh surface stretched among the truss cable is fixed in space.

This simple example shows that a rigid spatial truss can be formed by a cable assembly activated by proper forces exerted by a supporting structure. The concept is valid for any statically determinate truss configuration and it is called "the tension truss"(1).

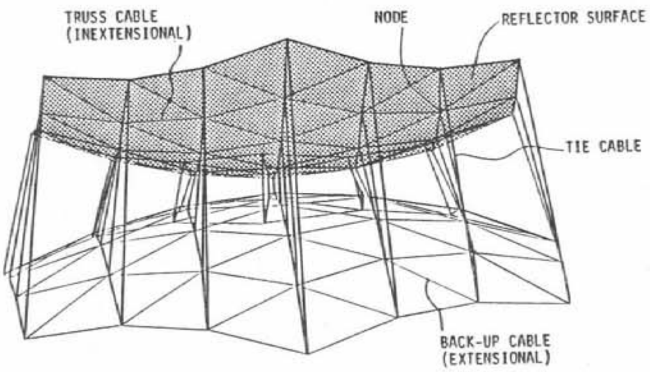
The concept of tension truss antenna can be considered as an extension of the above example. It takes full advantage of the fact a reflector surface is a surface of positive Gaussian curvature. In the upper part of Fig. 2, there is a system of truss cables forming a geodesic truss dome which simulates a parabolic surface; a mesh surface stretched among the truss cables provides a reflecting surface. In the lower part of the figure, there is a back-up and tie cable system facing to the truss cable system. The outward forces applied to nodes of the truss cable result in tensile forces everywhere in the truss cables. Thus a reflector surface is constructed in 3-space by a pre-tensioned truss cable structure, and it is called the "tension truss antenna."

Fig.1



Tension truss concept

Fig.2



Tension truss antenna (exclusive of support structure)

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The primary features of the tension truss antenna are summarized in the following.

a)The reflector surface is pre-determined by the lengths of truss cable members and their arrangement and is independent of forces within the cables.

b)It is the statically determinate truss.

c)The reflector shape adjustment can be done by changing lengths of truss cable members.

d)The antenna can be made light.

e)The concept is suitable for deployable antennas.

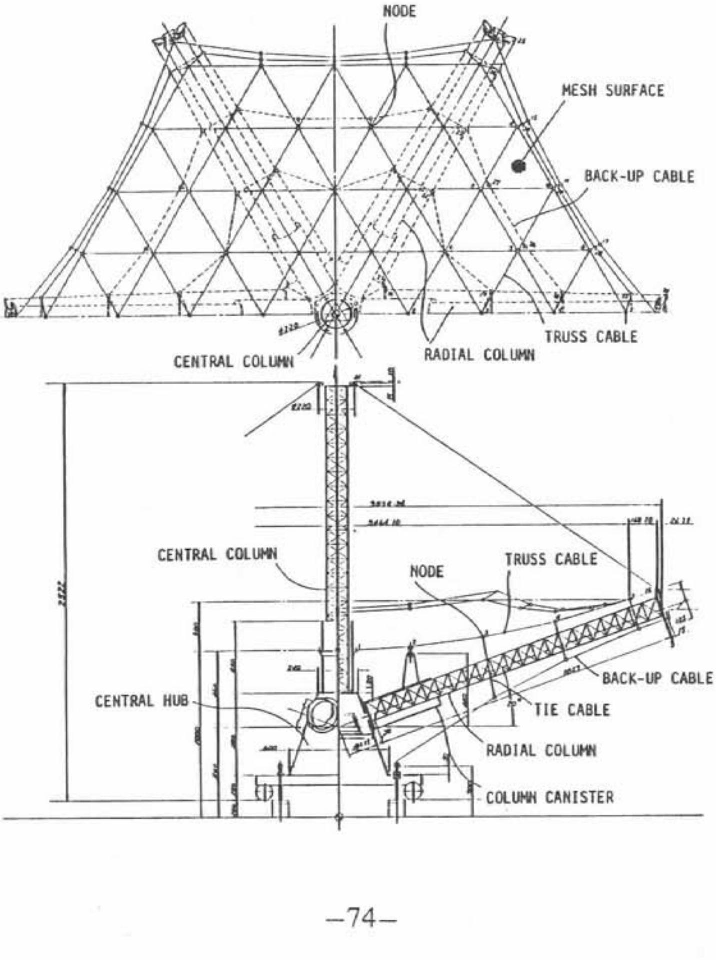
f)The freeplay in the joints is avoided by this pre-tensioned structure.

g)The arrangement and sizing of facets can be arbitrarily selected.

2. SYSTEM OF TENSION TRUSS ANTENNAS

A variety of deployable structures can be used for the support of cable assembly to form a tension truss antenna. These are, a hoop-column type, a radial rib type, and deployable truss types. As shown in an example of Fig. 3, the primary rigid structural elements of the antenna are the six extendible columns which deploy radially from the central pedestral supporting hub, and a central column which also deploys vertically from the hub. The truss cables, the back-up cables and the tie cables constitute an integral assembly to form a parabolic reflector surface. The cable assembly is stretched between the ends of radial columns and the central hub. Since the truss cable system has to be statically determinate, the boundary condition is selected so as to satisfy the Maxwell's equation.

Fig.3



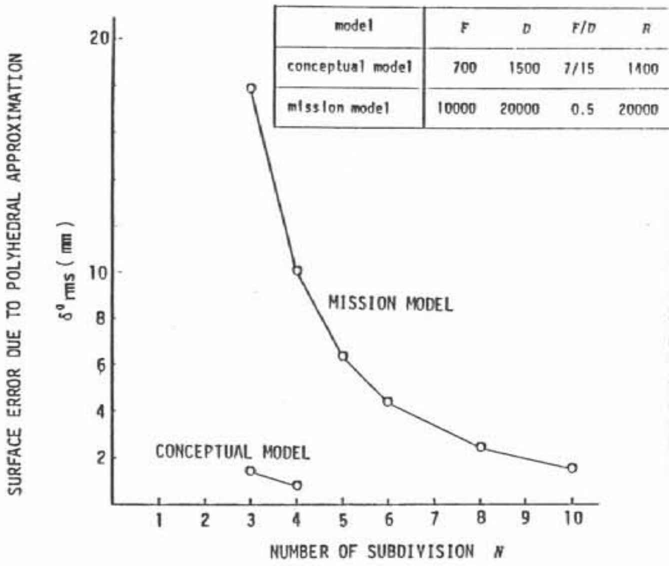
3. REFLECTOR SURFACE ERRORS

Among the sources of errors which should be considered, two of them are typical for a tension truss antenna. The first one is due to the approximation of a parabola by triangular facets and the other is due to the inaccuracy of member lengths.

The errors induced by polyhedral approximation has been discussed by Agrawal(2) and the result is equally applicable to the tension truss antenna. If the reflector under consideration is shallow, the facets tend toward equilateral triangles and the principal curvatures are nearly equal for any surface of revolution. Thus, the δ^0_{rms} calculation for an equilateral triangles on a spherical surface should be a good approximation for the actual geometry. This value is calculated for small conceptual models and larger mission models and the result is shown in Fig. 4.

The influence of member length errors on the surface deviation is calculated by Furuya. The computation of the error δ^*_{rms} is carried out and the result is shown in Fig. 5. From this figure, it can be said that for F/D = 0.5 and N = 4 5, the root-mean-square deviation is about 10 times of the standard deviation of member length errors. Another computation suggests that the error increases rapidly as F/D increases, it apparently shows the concept is most suitable for lower F/D ratio.

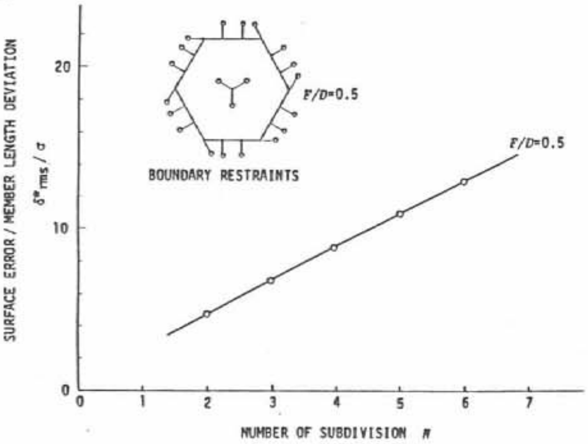
Fig.4



model	F	D	F/D	R
conceptual model	700	1500	7/15	1400
mission model	10000	20000	0.5	20000

SURFACE ERROR DUE TO POLYHEDRAL APPROXIMATION

Fig.5



INFLUENCE OF MEMBER LENGTH DEVIATION ON SURFACE ERROR

4. SURFACE SHAPE ADJUSTMENT ALGORITHM

One of the most important feature of the concept is that the surface shape adjustment can be done by changing the length of truss cable members. Any local deviation of a node can be adjusted by changing length of local(adjacent) truss members and it does not influence the other part of the truss. This feature is most desirable for both adjustment procedure on the ground and on-orbit adjustment.

In order to demonstrate this feature an antenna model as shown in Fig. 6 is treated. It is assumed at the initial state (0) there are deviations of nodes and slackening of truss cables(Fig. 7). Each black circle represents magnitude of the deviation of a node, and broken lines show slackened cables. A series of figures (1) to (4) in Fig. 7 demonstrate the result of sequential adjustment. If there is no slackened cable initially, single trial of adjustment is sufficient.

At present, on-orbit adjustment is very difficult to perform, however, the capability that the shape is controllable will become important in future application.

Fig.6

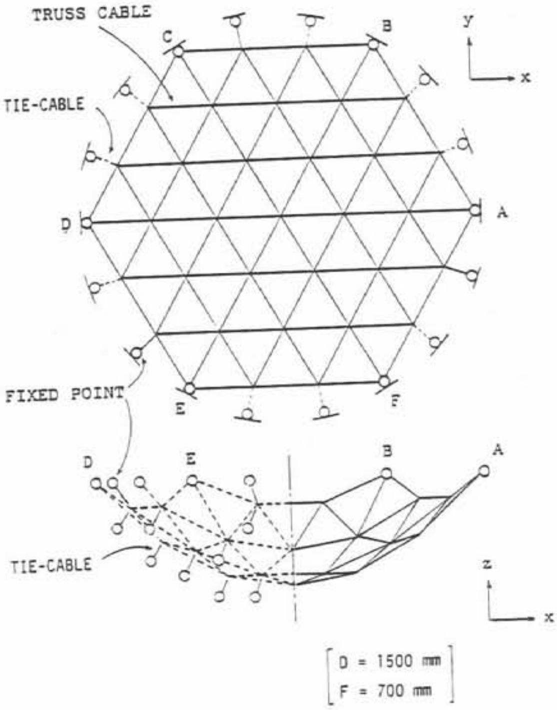
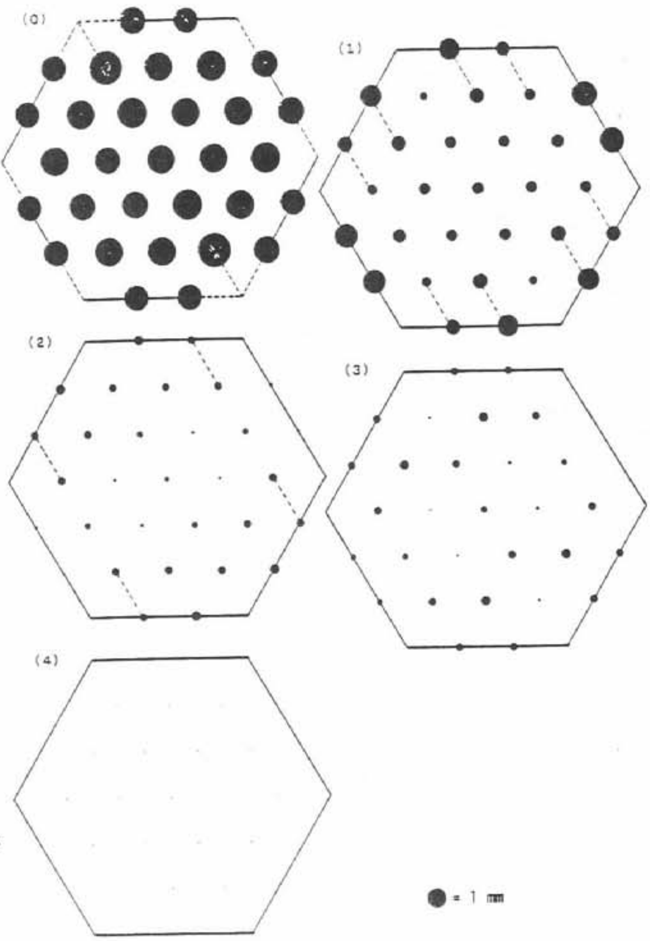


Fig.7



5. CONCLUDING REMARKS

As the tension truss antenna has many features especially suitable for a large space antenna, developing studies are in progress in several institutions and companies in Japan.

REFERECES

1)Miura, K.,"Concept of tension activated cable lattice antenna," 37th IAF, Innsbruck, Austria, 1986(Paper IAF-86-206).

2)Agrawal, P.K., Anderson, M.S., and Card, M.F., "Preliminary design of large reflectors with flat facets," IEEE Transactions, Vol.AP-29, No.4, July 1981.