SUBMILLIMETER ARRAY TECHNICAL MEMORANDUM

NUMBER : 55
SUBJECT : Dynamical analysis of the antenna
DATE : December 18, 1991
FROM : Philippe Raffin

This report shows the first natural frequencies of the antenna and corresponding mode shapes.

1. Description of the models

2 structural models are used, one for the whole antenna, the other for the reflector alone. The global model is built by merging the mount and the reflector structural models with proper release of the interface restraints (=elevation drive and elevation bearings)
The mount model is the latest and best performing one [1]. It has a 1.6 meter azimuth bearing, 1.8 meter elevation bearing spacing. It takes into account the foundations (2 meter in diameter).
The latest model of the reflector [2] is added to this model and calculation of the normal modes of vibration using the Simultaneous Vector Iteration method is performed with the FEM program I-Deas. The dynamical behavior of the reflector is then improved by modifying and adding structural elements. These changes are made on the model of the reflector alone in order to have shorter computing times. It has also been tried to support the secondary mirror with 8 spars instead of 4 and the results are mentioned here.

The model of the whole antenna has 2003 nodes, 3633 elements and 9602 degrees of freedom (DOF) or equations to solve, while the reflector itself has 1092 nodes, 2684 elements and 5644 DOF leading to about 1 hour 20' of elapsed computing time (less than half the time required for the whole model : 3 hours).

2. Back-up structure improvements

The first mode of the initial model of the BUS (described in Technical Memo #5 1) is a torsion of the back-up structure and occurs at a low frequency (6.35Hz). Referring to labels of Fig.2, the following modifications are then made :

- 16 cfrp cross bracings are added between nodes V and X (rear struts, AREA=350 mm^2)
- the pyramids BV are crossed
- 24 cfrp cross bracings are added between nodes X and Y (rear struts, AREA=250 mm^2)
- the cross-section of the radial struts XY is changed to 250mm^2

Fig.1 shows a top view of the rear struts and the "pyramids" of the BUS and Fig.2 shows a perspective view of a sector of the framework and of the hub, where the added members can be seen.
After these changes in the model, the first mode is a torsion of the quadrupod at 16.15Hz and the BUS first torsion mode is at 18.5Hz (model TAM24). The first 9 modes are :

f_1=16.2 Hz	torsion mode of the quadrupcxl
f_2=18.0 Hz	bending mode of the reflector (plane y,z)
f_3=18.5 Hz	BUS torsion mode
f_4=18.9 Hz	bending mode of the reflector (plane x,z)
f_5=25.3 Hz	bending mode of the reflector (plane x,z)
f_6=25.6 Hz	bending mode of the reflector (plane y,z)
f_7=36.6 Hz	BUS 90' "clam" mode
f_8=40.6 Hz	BUS 45" "clam" mode
f_9=41.8 Hz	reflector piston mode

If the base of the quadrupod legs is fixed instead of being pined, the torsion mode of the quadrupod occurs at a much higher frequency : 34Hz instead of 16.2 (Model TAM34).

3. The secondary mirror support

Fig.3 shows a model of an 8-legged support for M2, which is similar to JCMT's design. Its advantage is that it has a better rotational stiffness. However for the SMA antennas the shadowing due to the legs prevails. It will be at least 50% larger [3] when going from 4 to 8 supporting legs with proper stiffness. To have about the same blockage due to the 8 legs, they should be circular tubes of not more than 25mm in diameter, which is very unpracticable (buckling) and adds 5 natural bending and torsional modes of the legs with frequencies around 20Hz.

Therefore, it is preferred to have 4 legs with a sort of elliptical cross section (220mm x 50 mm).

Decreasing the mass of M2 and the wobbling system from 50 to 30kg only affects the modes above 25Hz (less than 10% increase of the natural frequencies).

4. Ring/hub interface

The interface between the hub and the ring, or more precisely the lower part of the hub and the upper part of the ring can be stiffened in order to increase the frequency of the first bending mode of the reflector which is around 20Hz, since a coupling can be noticed with the quadrupod legs (see Fig 5).

5. Foundations

The mount model shows a difference of 15% in the frequency of the first mode when the stiffness

of the 2m.foundations is taken into account (12.6Hz) and when the foundations are assumed to be rigid (14.8Hz). This seems to be a high figure compared to the IRAM 15m. antennas where a 5% deterioration was introduced due to the foundations.
Referring to the mount model for the zenith looking case [1], if the diameter of the foundations increases from 2 to 2.8 meters, the frequency increases by 13%, which will give a first mode at a frequency over 14Hz.

6. Natural frequencies for the reflector (model TAM34)

Assuming that the base of the quadrupod legs is rigidly fixed, we get the following modes :

f_1=18.4 Hz	BUS torsion mode
f_2=19.1 Hz	bending mode of the reflector (plane y,z)
f_3=20.2 Hz	bending mode of the reflector (plane x,z)
f_4=34.1 Hz	quadrupod torsion mode
f_5=35.0 Hz	bending mode of the reflector (plane y,z)
f_6=35.0 Hz	bending mode of the reflector (plane x,z)
f_7=36.6 Hz	BUS 90° "clam" mode
f_8=40.1 Hz	BUS 45" "clam" mode
f_9=41.8 Hz	reflector piston mode

Figures 5 to 8 show the 5th, 7th, 8th and 9th modes of the reflector.

7. Natural frequencies for the whole antenna

The lowest natural frequency of the whole telescope without the foundations is a bending mode of the mount at f=14.8Hz and is shown in Fig.4.

8. BUS Update

Fig.9 shows a sector of the BUS with the corresponding nodes, and Fig. 10 gives their coordinates in a cylindrical coordinate system having the Vertex of the paraboloid as origin and the boresight axis as z-axis.
Fig.1 1 indicates the thicknesses used for the constituting elements of the hub and the ring (Steel) and Fig. 12 is a layout of the secondary support and the quadrupod legs.

References

[1] Bill Davis, "Antenna Mount Design Study", SMA Tech.Memo#54, 1991
[2] Ph.Raffin, "Analysis of the reflector back-up structure", SMA Tech.Memo#51, 1991
[3] James Lamb, "Blockage due to subreflector supports in large radiotelescopes ". IEEE Proc. Vol 133, 1986

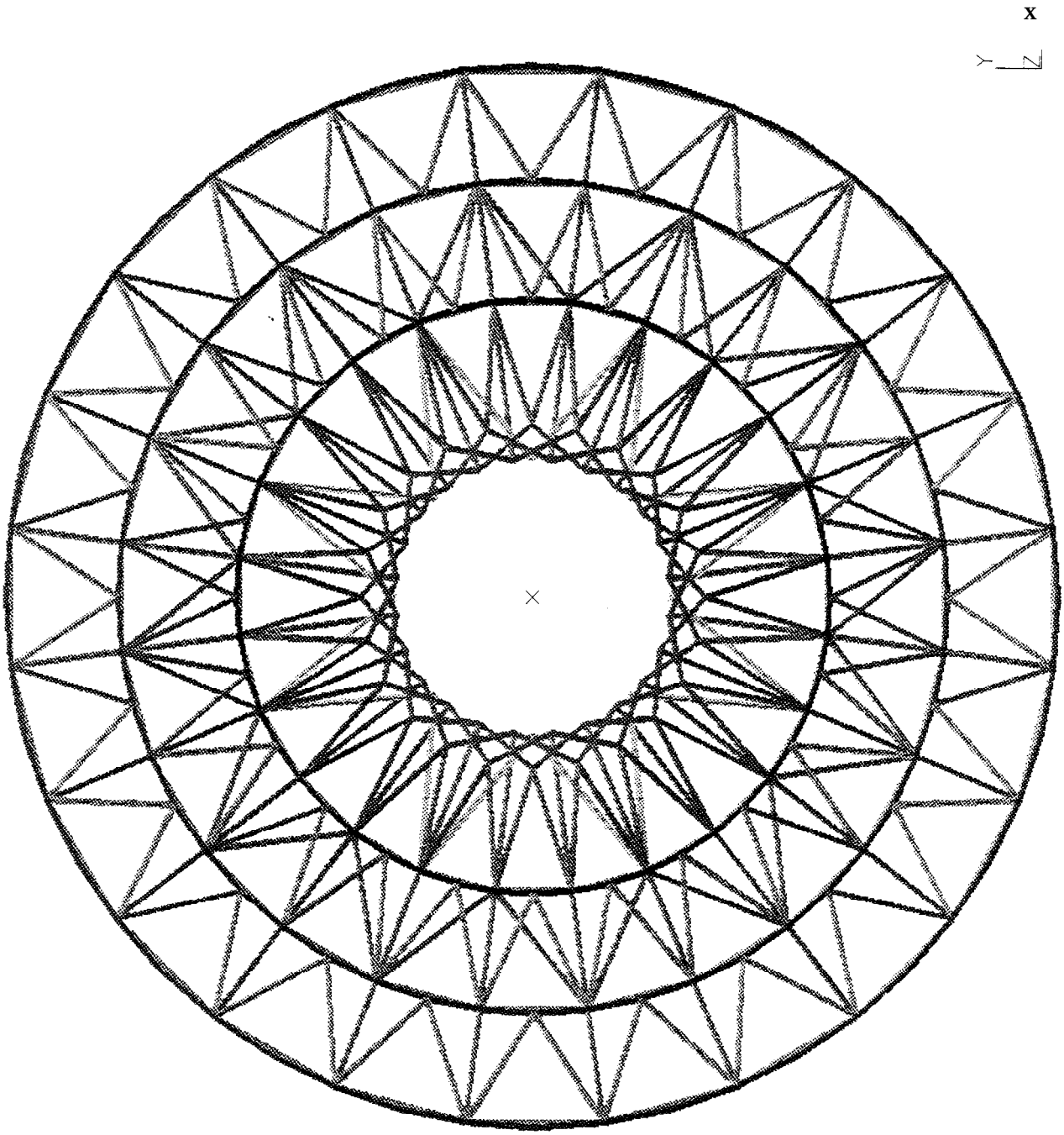

Figure 1: LAYOUT OF REAR STRUTS AND PYRAMIDS

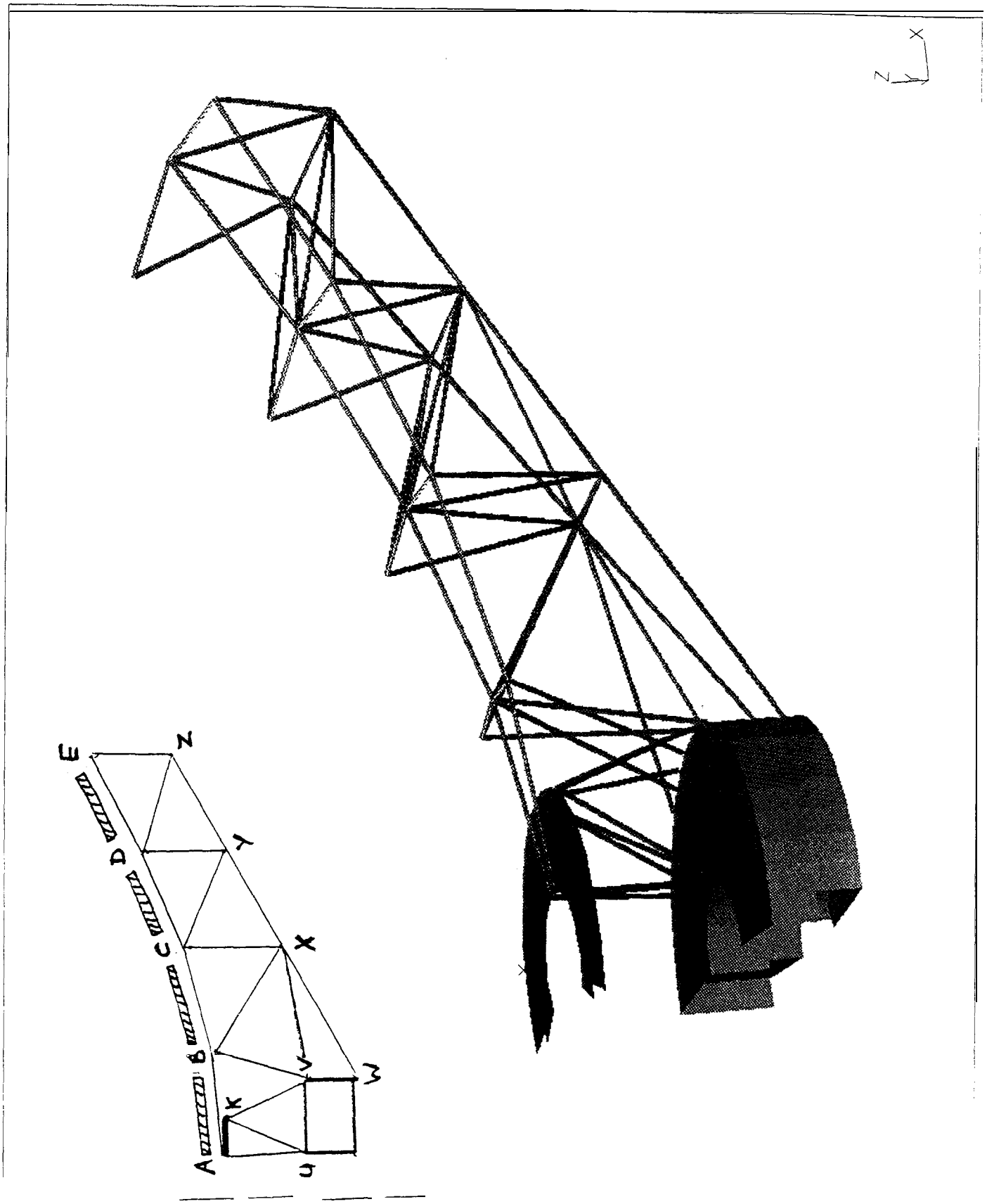

Fig.2 : PARTIAL VIEW OF THE REFLECTOR'S HUB AND BUS

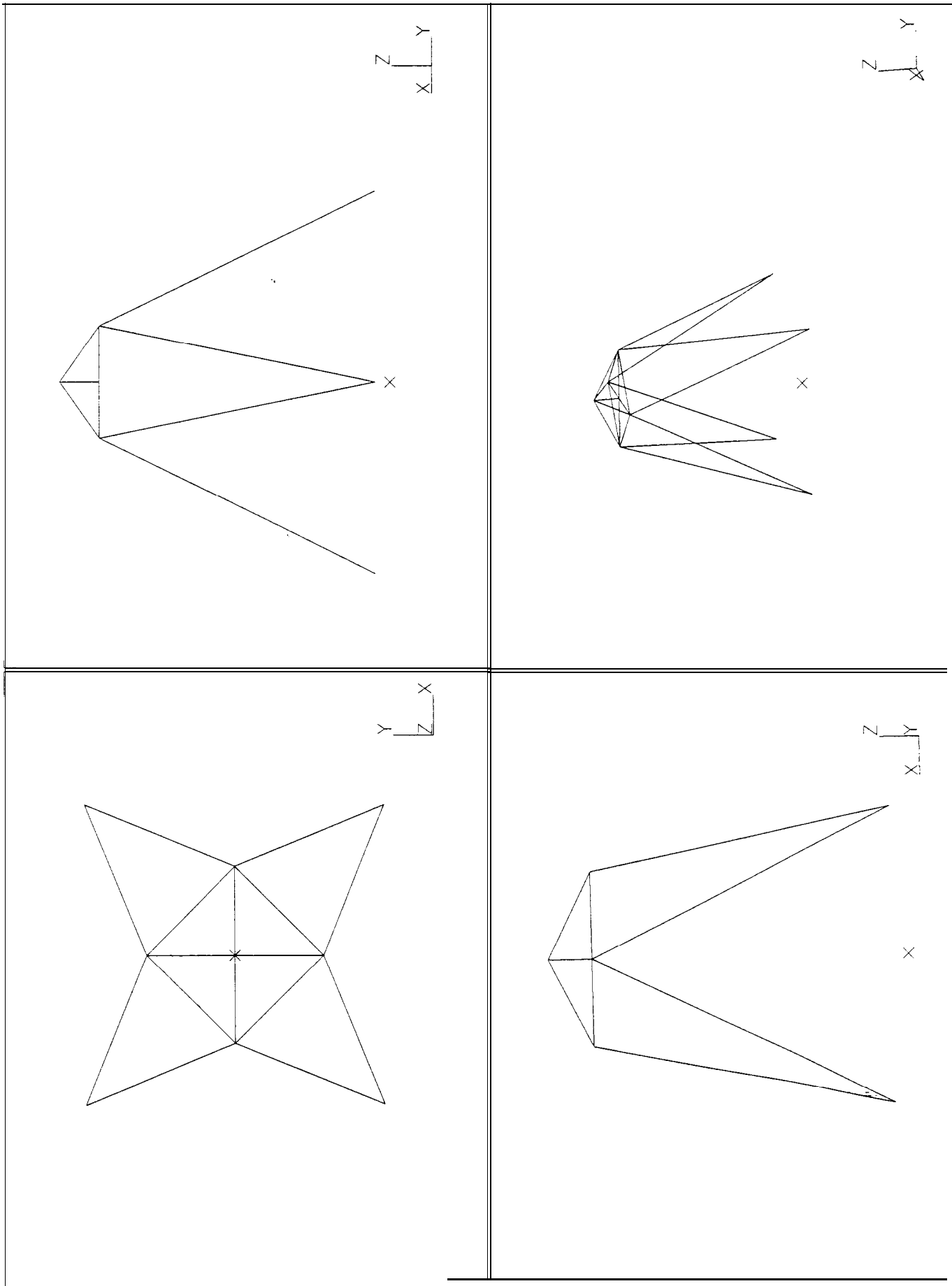

Figure 3 : QUADRUPOD DESIGN WITH 8 LEGS

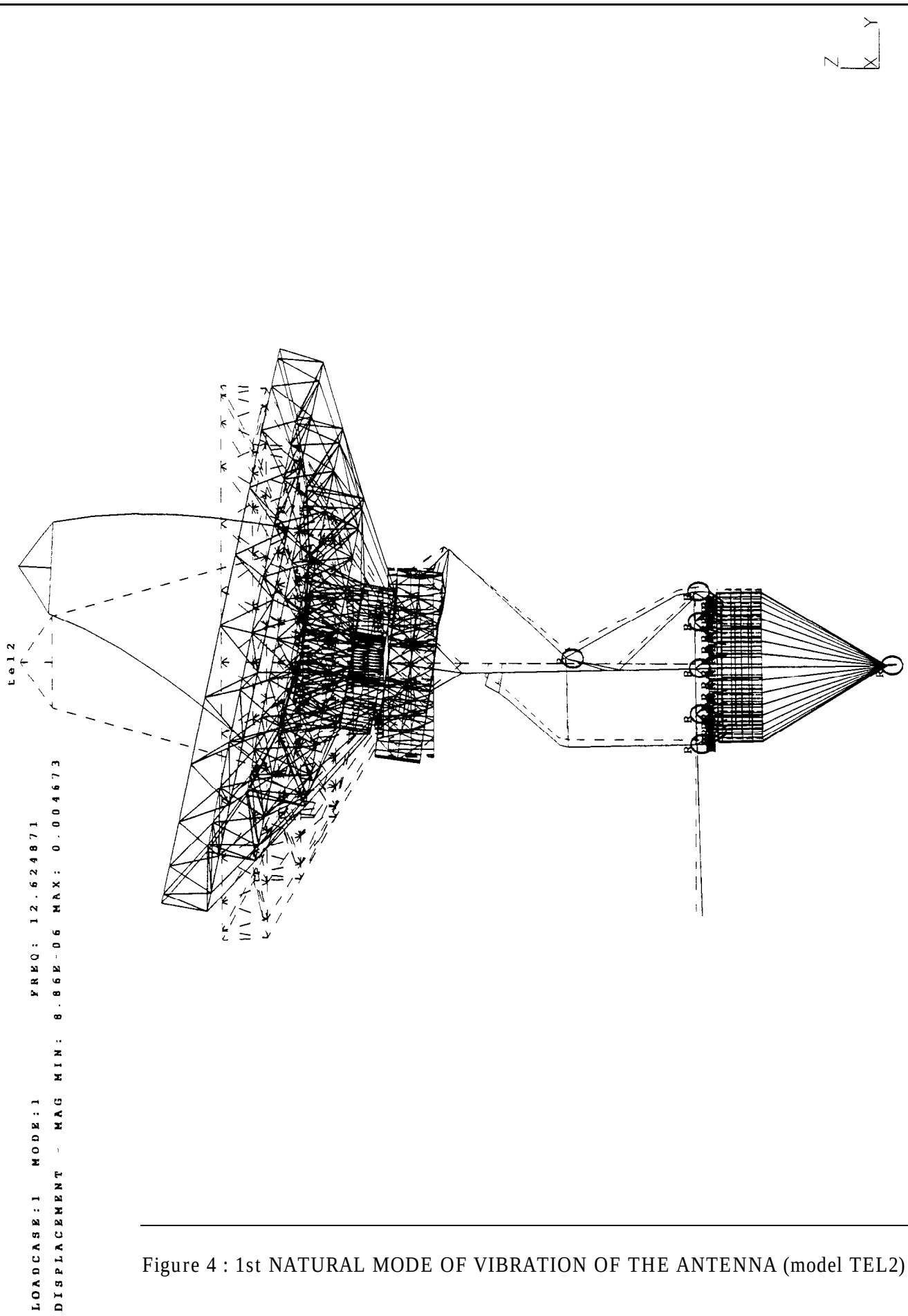

Figure 4 : 1st NATURAL MODE OF VIBRATION OF THE ANTENNA (model TEL2)

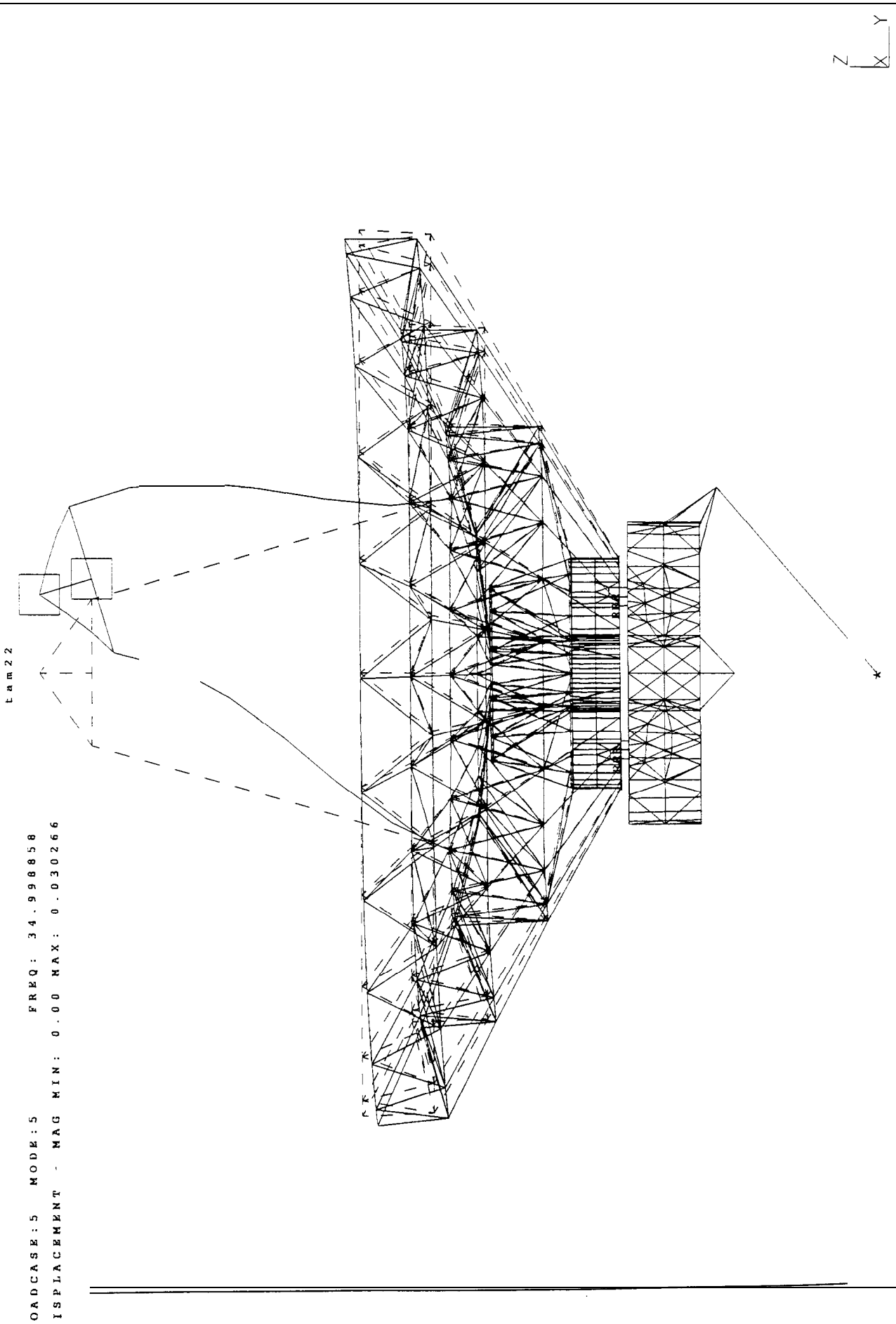

Figure 5 : 5th NATURAL MODE OF VIBRATION OF THE REFLECTOR (model TAM34)

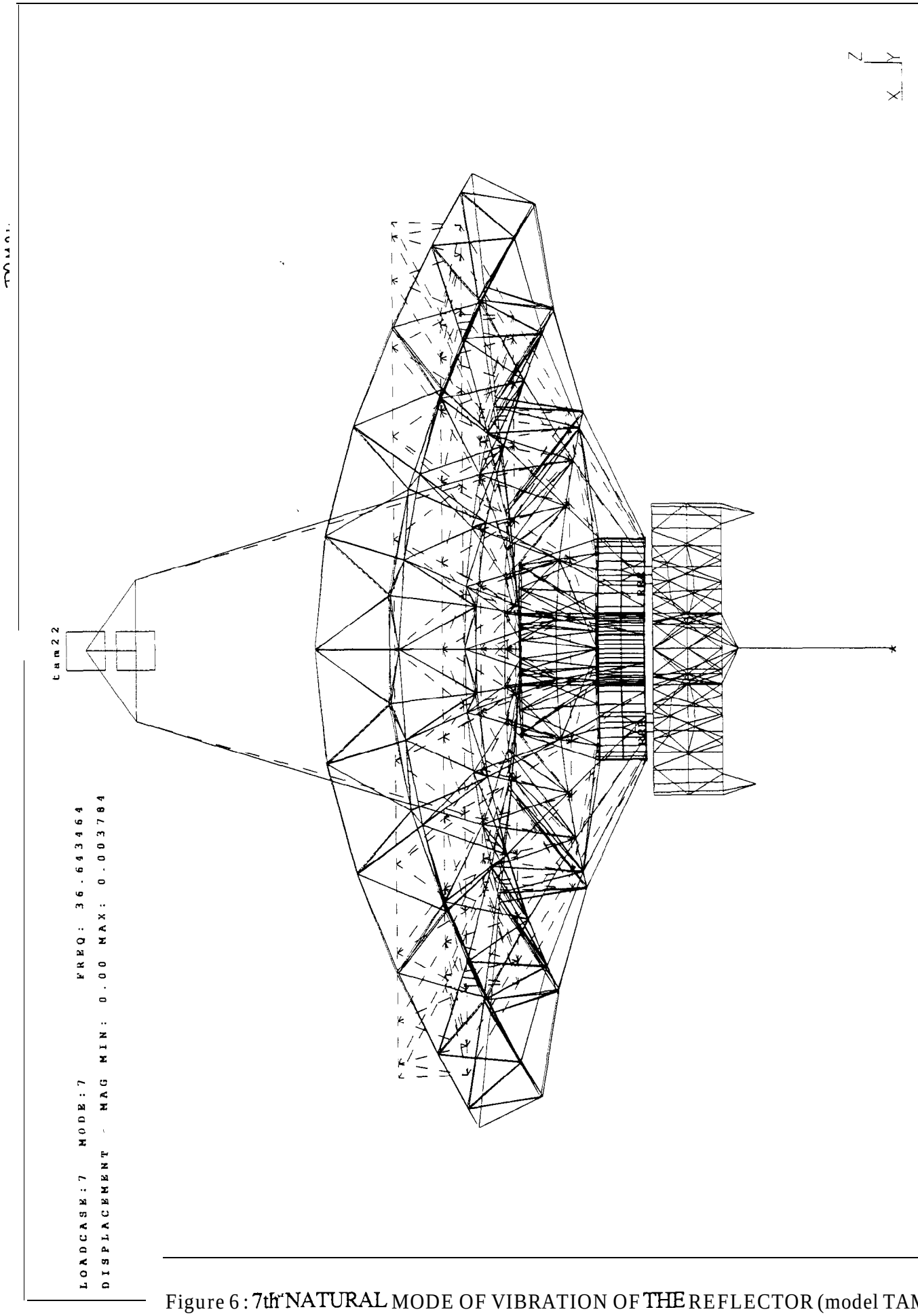

Figure 6 : 7th NATURAL MODE OF VIBRATION OF THE REFLECTOR (model TAM34)

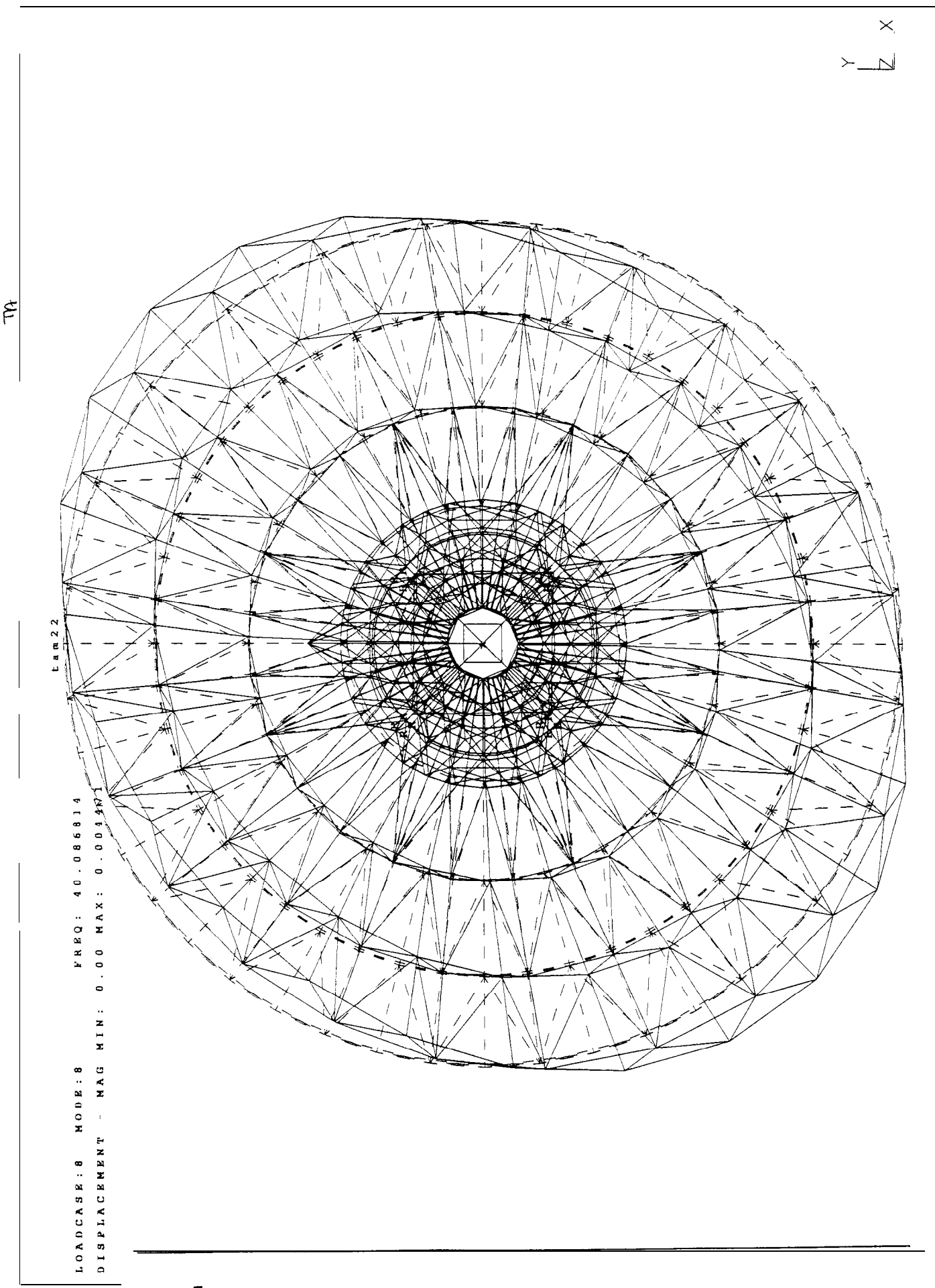

Figure 7.: 8th NATURAL, MODE OF VIBRATION OF THE REFLECTOR (model TAM34)

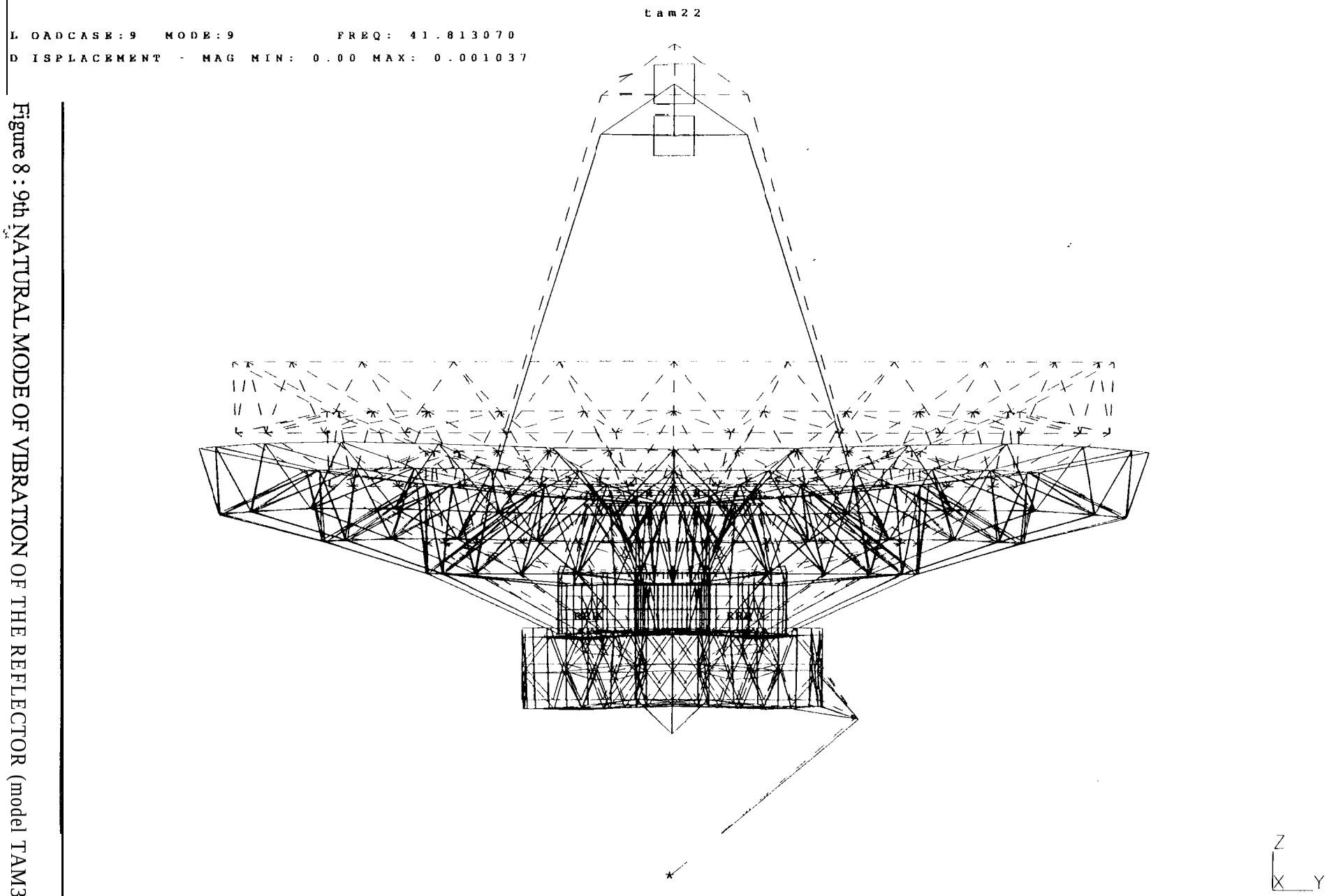

Figure 8 : 9th NATURAL MODE OF VIBRATION OF THE REFLECTOR (model TAM34)

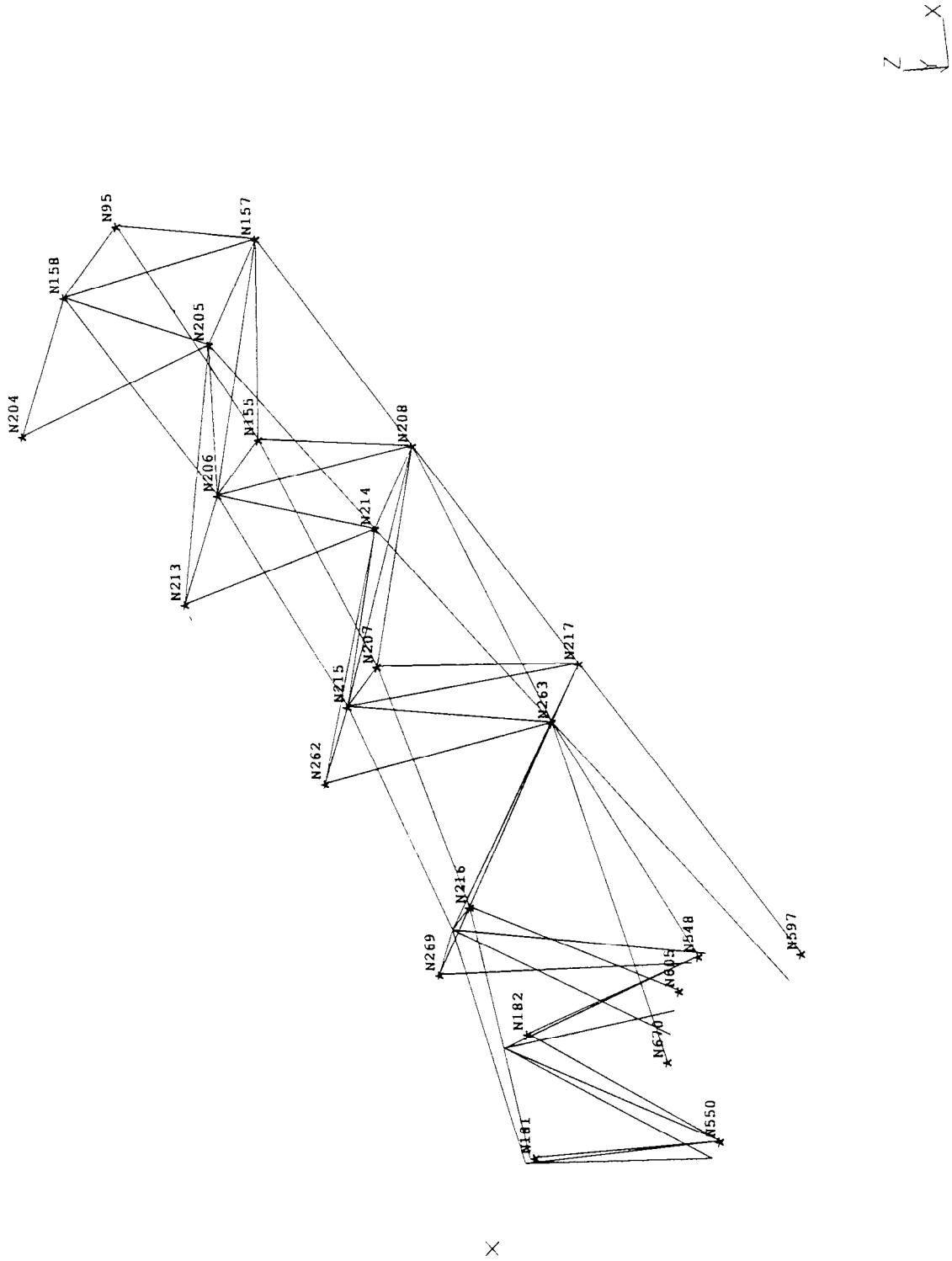

Fig.9 : NODE NUMBERS OF A SECTOR

(R,TH,Z) SI UNITS

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     95          1          0         11
3.0766999721527099D+00   0.0000000000000000D+00   7.6396000385284423D-01
    155          1          0         11
2.4195001125335693D+00   0.0000000000000000D+00   4.1475000977516174D-01
    157          1          0          8
3.0767201157375372D+00   7.4999998389886766D+00   2.6396000385284423D-01
    158          1          0         11
3.0767000009111904D+00   1.5000000400200804D+01   7.6396000385284423D-01
    181          1          0         11
2.5742998440611413D-01   3.4499999935051084D+02  -1.4360000193119049D-01
    182          1          1         13
6.1914331885361804D-01   3.4500009216829948D+02  -1.4358717203140258D-01
    204          1          0         11
3.0766998862465486D+00   3.0000000923636697D+01   7.6396000385284423D-01
    205          1          0          8
3.0767199371529034D+00   2.2500000446042996D+01   2.6396000385284423D-01
    206          1          0         11
2.4195000613867256D+00   1.5000000504764043D+01   4.1475000977516174D-01
    207          1          0         11
1.7264089584350585D+00   0.0000000000000000Dt00   1.3735599815845489D-01
    208          1          0          8
2.4195137141368689D+00   7.4999998423239135D+00  -1.1352038383483886D-01
    213          1          0         11
2.4195002021542202D+00   3.0000002034385392D+01   4.1475000977516174D-01
    214          1          0          8
2.4195136739021876D+00   2.2499999827695315D+01  -1.1352038383483886D-01
    215          1          0         11
1.7264089511662614D+00   1.5000000503820592D+01   1.3735599815845489D-01
    216          1          0         11
1.0025000572204589D+00   0.0000000000000000Dt00  -5.3137000650167465D-02
    217          1          0          8
1.7264167755427150D+00   7.5000017823578790D+00  -5.1057767868041992D-01
    262          1          0         11
1.7264089181851323D+00   3.0000000771229117D+01   1.3735599815845489D-01
    263          1          0          8
1.7264168720607919D+00   2.2499999304129591D+01  -5.1057767868041992D-01
    269          1          0         11
1.0025000659794480D+00   2.9999999710977537D+01  -5.3137000650167465D-02
    548          1          1          1
8.0000162126554243D-01   3.9700394094915566D-04  -7.1055901050567626D-01
    550          1          1          5
2.5743150711204649D-01   1.9235746252743053D-04  -7.1053969860076904D-01
    597          1          1          1
8.0000007921936084D-01   7.4999996990035180D+00  -1.0436199903488159D+00
    605          1          0          1
7.9999998818607487D-01   2.2499999964519783D+01  -7.1057999134063720D-01
    670          1          1          1
8.0000016332534809D-01   4.4999996981454927D+01  -7.1055996417999267D-01--
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Fig. 10 : NODES COORDINATES OF SECTOR OF Fic.9

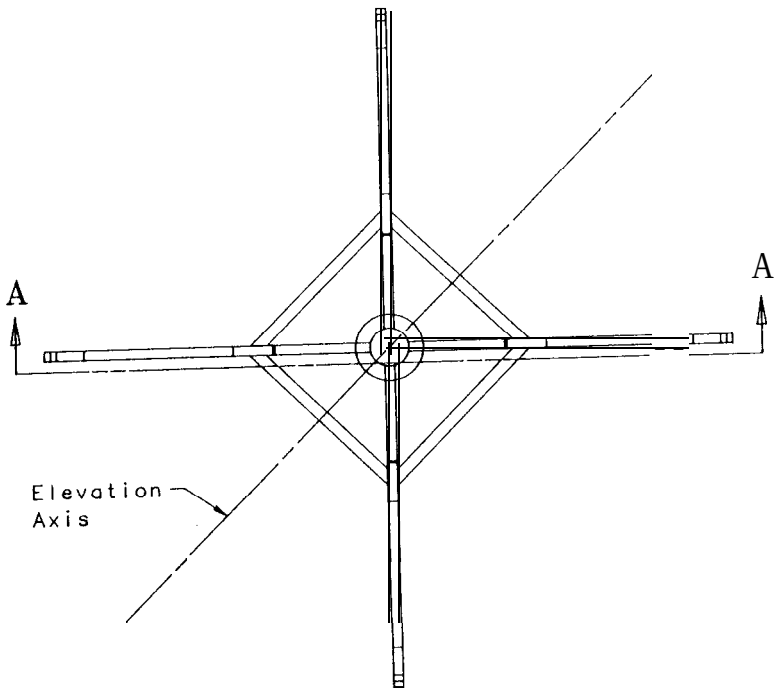
l.THEHUB

TOP RING	10
MEDIAN RING	6
BOTTOM RING	12
INNER CYLINDER	6
OUTER CYLINDER	6
STIFFENERS	4

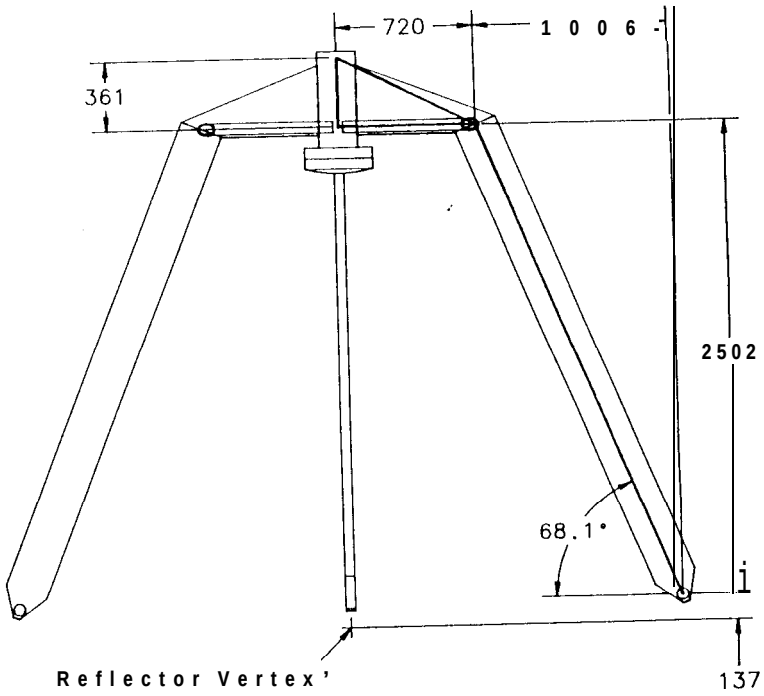
2. THE RING

TOP RING	12
BOTTOM RING	6
INNER CYLINDER	6
OUTER CYLINDER	6
STIFFENERS	6
LOCAL REINFORCEMENTS	20
(to El-drive, El-bearings supports)	

Fig. 11 : HUB, RING : THICKNESS (IN MM)



Plan View



View A-A

Figure 12