PROJECT REPORT

1985–86

DESIGN AND CONSTRUCTION OF A

Ground Station Dish Antenna

PROJECT GUIDES

MR. A. N. VENUGOPAL

(B.M.S. College of Engineering, Bangalore-560 019)

MR. MANOHAR MODGEKAR

(Raman Research Institute Bangalore-560 080)

PROJECT TEAM

Madhusudan Matta

Manoj Suvarna

Sita Gopalan

N. Rama Kanth

Jacob J John

DEPARTMENT OF MECHANICAL ENGINEERING

B. M. S. COLLEGE OF ENGINEERING

Bangalore - 560019.

ACKNOWLEDGEMENT

The project work involving DESIGN AND CONSTRUCTION OF GROUND STATION DISH ANTENNA which was undertaken at the Raman Research Institute, Bangalore, has just been completed.

We would like to express our grateful thanks to Professor V. Radhakrishnan, Director, Raman Research Institute, Bangalore, for giving us the opportunity to work at the Institute.

This project would not have been successfully completed without the guidance, support and assistance received from Mr.Manohar of the Institute, who involved himself personally throughout the project work with utmost dedication.

We owe a deep debt of gratitude to Mr.A.N.Venugopal, Dept., of Mechanical Engineering, B.M.S.College of Engineering, Bangalore, for his valuable guidance and unstinted support without which the project would not have made any head-way.

Our thanks go to Dr.Harnath, Professor and Head of Dept., Department of Mechanical Engineering, B.M.S.College of Engineering, Bangalore, for his consent.

RAMAN RESEARCH INSTITUTE

BANGALORE-560 080 INDIA

V. RADHAKRISHNAN
DIRECTOR

23 January 1987

THIS is to certify that the following students of B.M.S. College of Engineering, Bangalore have successfully completed their project on **'Design and Construction of a Ground Station Dish Antenna'** during the period July, 1986 to January 1987.

M/s. Manoj B. Suvarna
Jacob J. John
Madhusudhan Matta
Sita Gopalan
N. Ramakanth.

Director
Raman Research Institute
Bangalore 560 080

B.M.S.COLLEGE OF ENGINEERING - BANGALORE 560 019

CERTIFICATE

This is to certify that the project work entitled 'DESIGN AND CONSTRUCTION OF A GROUND STATION DISH ANTENNA' has been satisfactorily completed by the students listed below, at the Raman Research Institute, Bangalore, towards partial fulfilment of the curriculum prescribed by the Bangalore University for the Final Year B.E. (Mech) Course. 1985-86.

PROJECT TEAM :

MADHUSUDAN MATTA
MANJO B. SUVARNA
SITA GOPALAN
N. RAMAKANTH
JACOB J. JOHN

PROJECT GUIDES :

Modgekar

Mr.Manohar Modgekar
(Raman Research Institute)

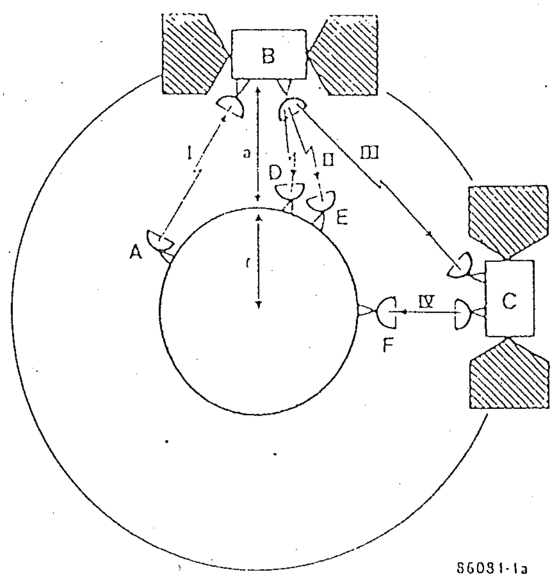
Dr.S.Harnath
Head of Dept.
Dept. of Mechanical Engg.
B.M.S.College of Engg.

Mr.A.N.Venugopal
Dept. of Mechanical Engg.
B.M.S.College of Engg.

Dr.H.R.Viswanath
Principal
B.M.S.College of Engg.

INTRODUCTION AND DESIGN CONSIDERATIONS FOR CONSTRUCTION OF A GROUND STATION DISH ANTENNA

PERFECT INTEGRATION OF MECHANICAL ENGINEERING, ELECTRONICS AND SATELLITE COMMUNICATION.



A = uplink station for TV and data comms
B,C = geostationary satellites
D,E = CATV/SMATV stations
F = data reception station
I = uplink (14/17 GHz; 70...95 dBW EIRP)
II = downlink (11 GHz; 40...48 dBW EIRP)
III = sat-sat cross strap (11GHz)
IV = data downlink

not to scale

SECTION 1

INTRODUCTION

The world's first mention of satellite communication was made by Arthur.C.Clarke in the "Wireless World" journal dated February 1945. This was essentially a theoretical discussion of the subject.

In 1955, John Pierce of Bell Laboratories put forth the theory of the "Active" and "Passive" satellite.

THE PASSIVE SATELLITE

The Passive Satellite inducted the principle of simple reflection. The idea was practically pioneered in "Project Echo", which used an aluminated balloon to bounce signals beamed from the ground.

THE ACTIVE SATELLITE

Pierce suggested a satellite system which would not just reflect signals but process and retransmit them. So in the year 1962, the world's first active satellite was commissioned. However this was not a truly succesful project because the satellite was a drifting one,and disappeared from view.

With the goal and incentive that if succesful, the opportunities would be limitless, scientists carried on their research, and in 1963, the first truly active satellite was born in SYNCOM - world's first geo-stationary satellite.

This project was undertaken with the objective to design and construct an antenna for a ground station. To achieve this considerable study was necessary in the field of satellite communication as detailed in this report.

SECTION 2

SATELLITE COMMUNICATION

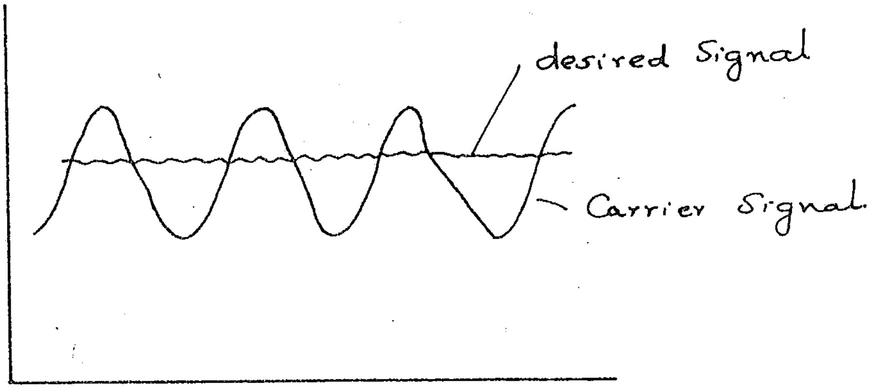
This section deals with a study of certain important parameters in satellite communication, which are essential to our design.

NOISE

Since noise or specifically white noise (synonymous with white light), plays such an inherent part in satellite communication and reception, it was essential to estimate the amount of noise that will be present in the system. The quality of reception will depend on maximizing the signal-to-noise ratio.

Today satellite communication involves frequency ranges essentially between 3-4.5 GHz and 10-13 GHz. The signal to be transmitted is modulated onto a carrier frequency in the ranges mentioned above and then transmitted. The active satellite receives this frequency and retransmits the entire information at a slightly different downlink frequency.

While recieving and demodulating the desired signal, it is necessary to filter out all extraneous signals in the bandwidth. These extraneous signals are collectively termed NOISE. We see that the sky itself behaves as a huge black body and emits radiation in all wavelengths. It is important to note that for succesful reception signal:noise



ratio must be greater than 20

i.e. S/N 20

It is hence of utmost importance to determine the power of the undesired noise signal.

EQUIVALENT NOISE TEMPERATURE

Consider a resistor at room temperature. If a sensitive A.C voltmeter is connected across its terminals, a deflection is observed. This is because of the random fluctuations of the molecules which compose the resistor. This "thermal noise power" is proportional to the temperature of the resistor(in K) and also to the bandwidth of the voltmeter that is used.

$P = K\ T\ B$ watts

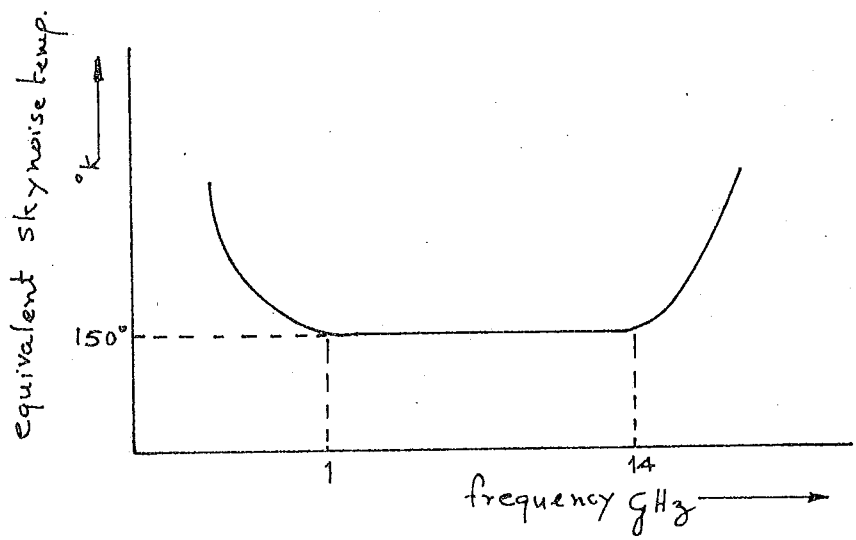
where K = the Boltzmann's constant = 1.38 x 10 J/ K

T = temperature of the resistor (K)

B = bandwidth of the voltmeter (Hz)

Other noise sources are said to have an equivalent noise temperature T if its output noise power is equal to that produced by a resistor maintained at a temperature of T .

As mentioned earlier the sky itself behaves as a black body and emits radiation in all wavelengths. If a graph of equivalent sky noise temperature versus frequency is plotted, the following curve is obtained.



It can be seen from the graph that noise emitted from the sky is at a minimum for the band extending from 1-14 GHz. Equivalent noise temperature corresponds to approximately 150 K.

Hence for signals between 1 and 14 GHz we obtain the concept of the SATELLITE WINDOW, synonymous to the radio window. With these limits in mind we chose to design our dish for reception.

Within the satellite window higher frequency ranges are desirable i.e. 11-12.5 GHz. This may be explained as follows:-

$\lambda \times f = c$ where λ = wavelength

f = frequency

c = velocity of light

= 3 x 10 m/s

Now the gain of the dish is inversely proportional to the square of the wavelength of the desired signal, or in effect is directly proportional to the square of its frequency. Hence greater the frequency range of the signal, the less the required dish size. However it must be remembered that for these higher frequency ranges, tremendous accuracy is required in the construction of the dish. Surface irregularities must be kept below /20.

Keeping these factors in mind, our dish was designed and constructed for reception of signals in the frequency range of 3 - 4.5 GHz.

RECEIVER AND SYSTEM NOISE POWER

The signals collected by the dish are analysed as electrical signals. To boost the power of the recieved signal, recieving equipment has an amplifier and these inherently produce noise. This is the reciever noise.

The pertinent question is will the signals from the distant satellite be clear or not, i.e. will S/N ratio be greater than 20.

The equivalent noise power any reciever produces is calculated from:

P (rec) = K T B watts

The overall system noise is calculated from:

P (sys) = K (T + T) B watts

where

K = Boltzmann's Constant = 1.38 x 10^{-23} J\°K

T = Reciever equivalent noise temperature °K

T = Antenna equivalent noise temperature (approx 150°K)

B = Reciever band width Hz

Our system temperature will attain a value of about 300 K at an ambient temperature T of approximately 295 K. T depends on a large number of factors including equivalent noise temperature of galactic, atmospheric and man-made interference at the frequency of reception while the degree of dish smoothness (surface irregularities), reflective qualities, f/D ratio etc. also play a distinct role.

NOISE FACTOR AND NOISE FIGURE

Consider our LNA (low noise amplifier) mounted at the focus of our dish.

T_o = room temperature

T_r = equivalent noise temperature of amplifier.

The output voltage of the LNA is given by

$C (T_o + T_r) = N_1$ where N - output voltage

C - a constant

For an ideal amplifier

$C T_o = N_2$

$$\frac{T_o + T_r}{T_o} = \frac{N_1}{N_2}$$

This ratio $\frac{N_1}{N_2}$ is the NOISE FACTOR F.

The value 10 log F = NOISE FIGURE (db)

DECIBEL GAIN

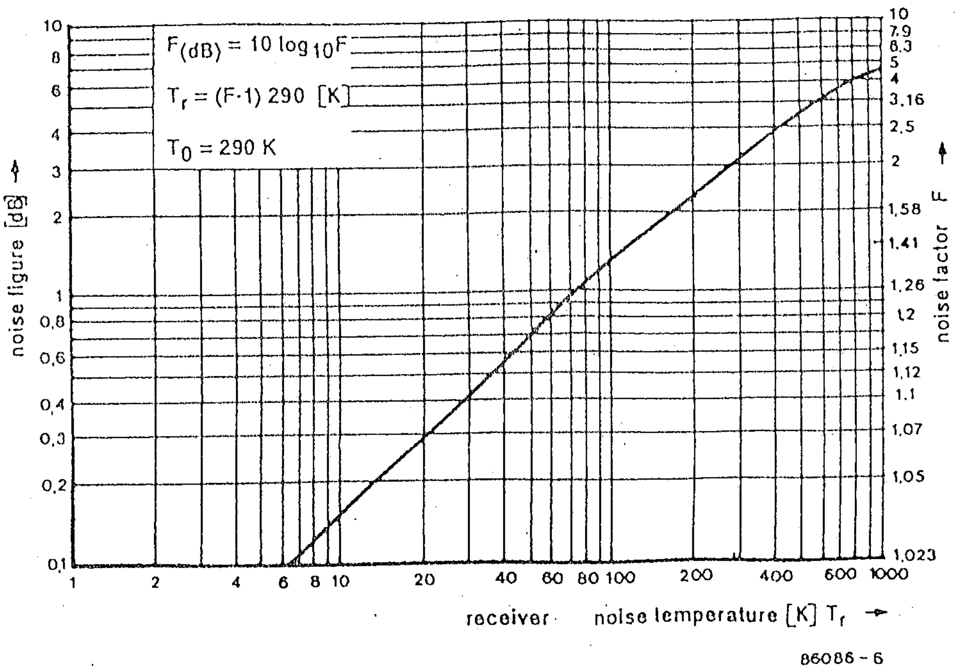
Mention may be made here of this unit of gain as it is the one chiefly used in reception and hence in many of our calculations.

Although the gain of an amplifier can be expressed as a number, it is of great practical importance to assign it a unit. The unit assigned is the Bel or the Decibel. The log of power gain is called Bel.

$$\text{Power Gain} = \log_{10} \frac{P_{out}}{P_{in}} \quad \text{Bel}$$

$$= 10 \log_{10} \frac{P_{out}}{P_{in}} \quad \text{dB}$$

Since this is a logarithmic unit, overall gain of a multistage amplifier is the Sum of gains of individual stages in dB.



dB = P milliwatt

P

dB = P watt

P

If P is a fixed power, then we get absolute power representation for power. Normally, P is taken to be equal to 1 mW. Then P expressed in logarithmic unit is called dBm.

dBm = 10 log P (P in mW)

SECTION 3

SATELLITES

For the design of our dish system it was necessary to determine the radius of the geo-stationary orbit.

The centripetal force exerted by the earth on the satellite = $m R \omega^2$

The force of attraction (from Newtons law) = $\frac{G M m}{R^2}$

where

m = mass of the satellite

M = mass of the earth = 5.97×10^{24} kgs.

ω = angular velocity = $2\pi / T$ m/s

G = gravitational constant = 6.673×10^{-11} $m^3/kg/s^2$

R = Distance from the centre of the earth to the geo-stationary orbit

T = siderial period of the earth's rotation = 23' 56"

$$m R \omega^2 = \frac{G M m}{R^2}$$

$$R = \sqrt{\frac{G M}{(2\pi / T)^2}}$$

$$R = \frac{G\,M}{(2\;\;/\;T)}$$

On substituting R = approx. 42400 kms.

Distance above the earths surface = 42400 - radius of the earth

= 42400 - 6400

= 36000 kms.

An accurate value of the altitude of this orbit may be obtained from the equation :

$$T = 1.40818333 \quad (a/r) + 1$$

where

T = time period of 23 56

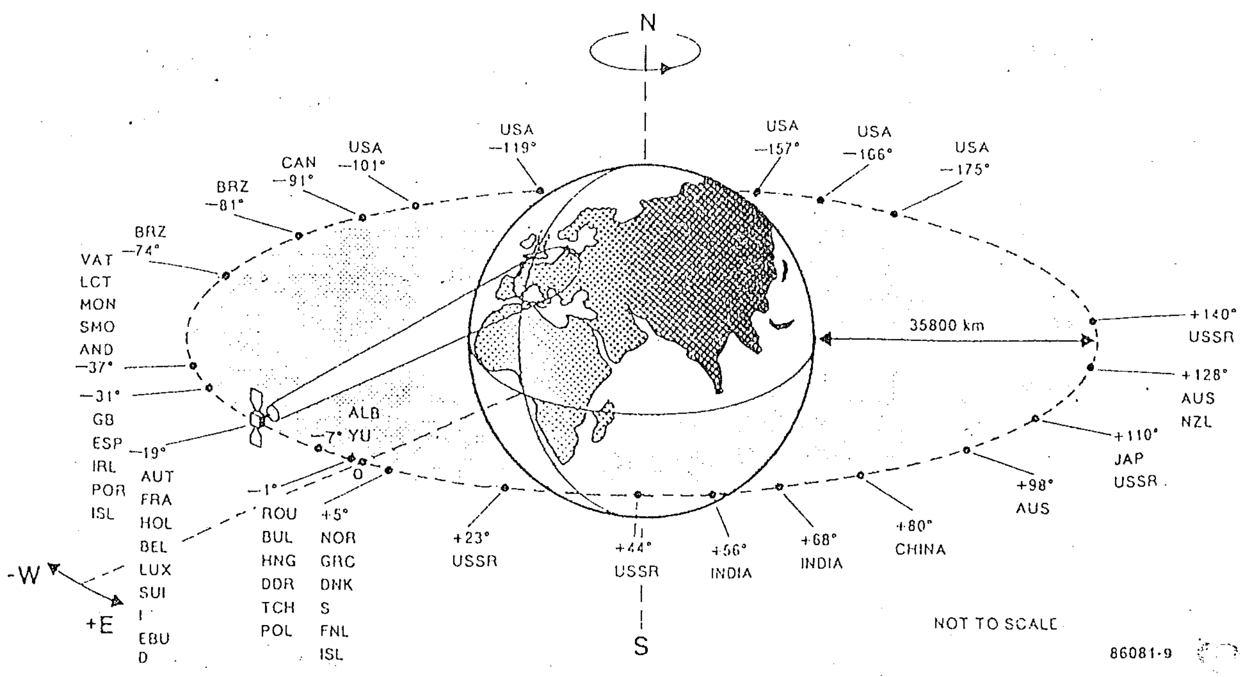
a = altitude of the satelitte above the equator (k

r = mean radius of the earth = 6371 kms.

$$23.933 = 1.40818333 \quad (a/6371) + 1$$

$$a = 35{,}822 \text{ kms.}$$

Satellites in the geo-stationary orbit are specified by longitude above which it is launched.



The geo-stationary orbit is already quite crowded with communication satellites and regulatory action is called for on the part of WARC (World administrative Radio Conference) to ensure orbital spacing of not less than 0.2 (about 150 kms.). A servicing orbit is being considered for spare as well as defective satellites at approx. 100 kms. furthur into space.

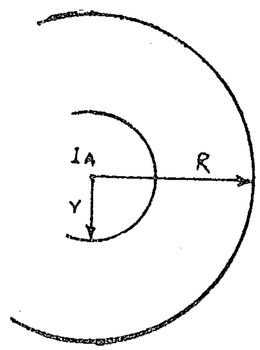
Although gravitational and centrifugal forces are at equilibrium in the orbit, satellites are nonetheless frequently repositioned by the relevant uplink control centre which obtains its information from monitoring telementary stations. Such positional corrections are called for to compensate for satellite movement owing to fluctuations in the earths magnetic field or possible collisions with stray matter.

SECTION 4

ANTENNA

The satellite is essentially a repeater station. It recieves the programs from the TV studio via a suitable transmitter and then retransmits it back to the earth. Transmission signals are beamed and collected with the help of antennae.

An antenna may be DIRECTIVE or ISOTROPIC. An isotropic antenna is one which radiates power equally in all directions.



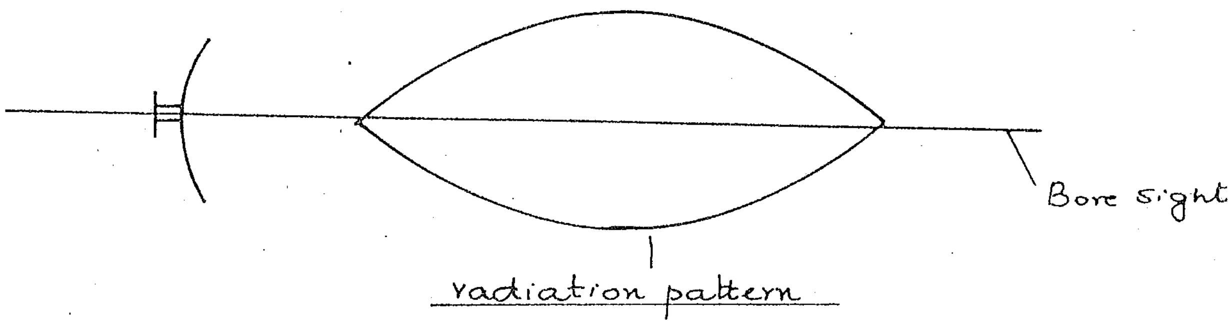
Consider an isotropic antenna IA radiating power.

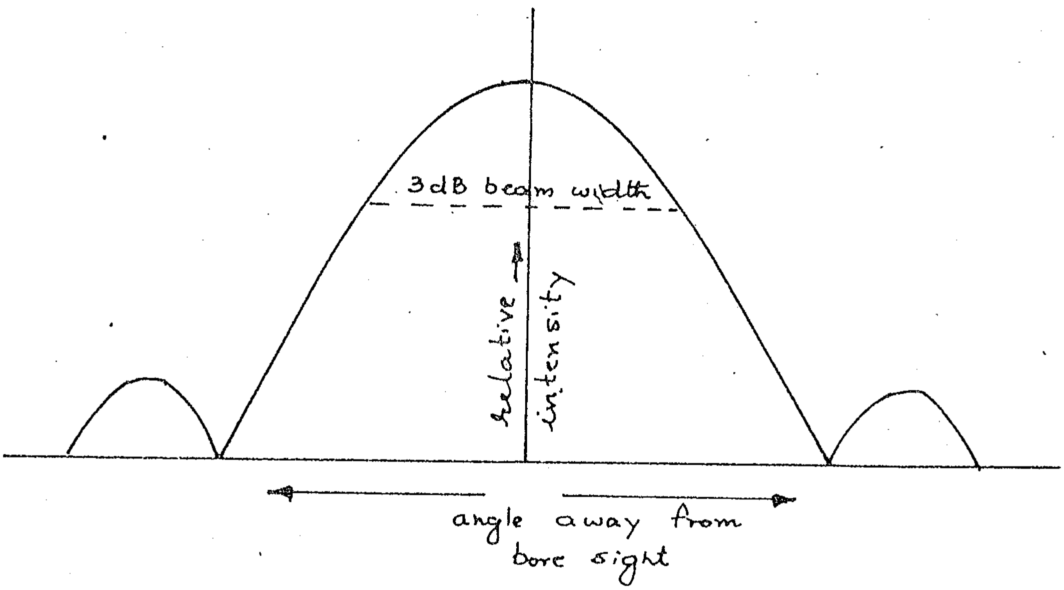
At a distance of r the power is spread over a spherical area = 4 r

At a distance of R the power is spread over a spherical area = 4 R

It is obvious that for an isotropic antenna power is diluted in proportion to the square of the distance from transmission.

As opposed to the isotropic antenna we have the Directive antenna which transmits power in a selective direction. For a particular direction the directive antenna has a radiation pattern.





The 3 dB beam width is denoted as Half Power Beam Width (HPBW)

$$HPBW = 70 \frac{\lambda}{D}$$

where

λ = wavelength (cm.)

D = Diameter of the dish (cm.)

$$\text{Gain of the antenna on any point on the bore sight} = \frac{\text{Power recieved from directive antenna}}{\text{Power recieved from isotropic antenna}}$$

Gain of an isotropic antenna = 1

Gain in any other direction = $G(\theta, \phi)$

where

(θ, ϕ) are co-ordinates in the spherical system.

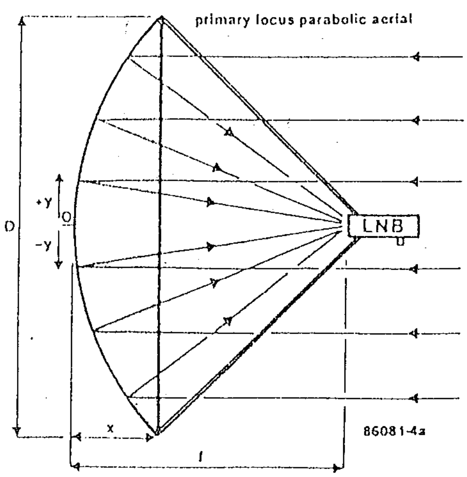
To receive the satellite signals, a receiving aerial popularly called a dish antenna or just a dish is required.Our project involves construction of this dish.The dish must have an unobstructed view of that part of the sky where the satellite is located.

The parabolic reflector receives power from the element at its focus and reflects it forward over a wide area.The problem of detecting radio waves from a point in the sky is the opposite problem of collecting the radiation falling on as large an area as possible,and concentrating it at one place so that it can be fed into a radio receiver.A PARABOLIC reflector with a receiving horn at its focus lends itself perfectly to this problem.

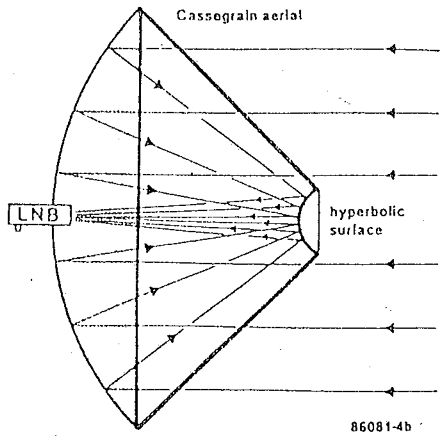
In addition,the parabolic reflector dish is probably the only suitable type of aerial to offer sufficient gain at frequencies above 2.5Ghz. Hence we had no hesitation in incorporating this into our design.

The figure below shows a number of dish types.

a



b

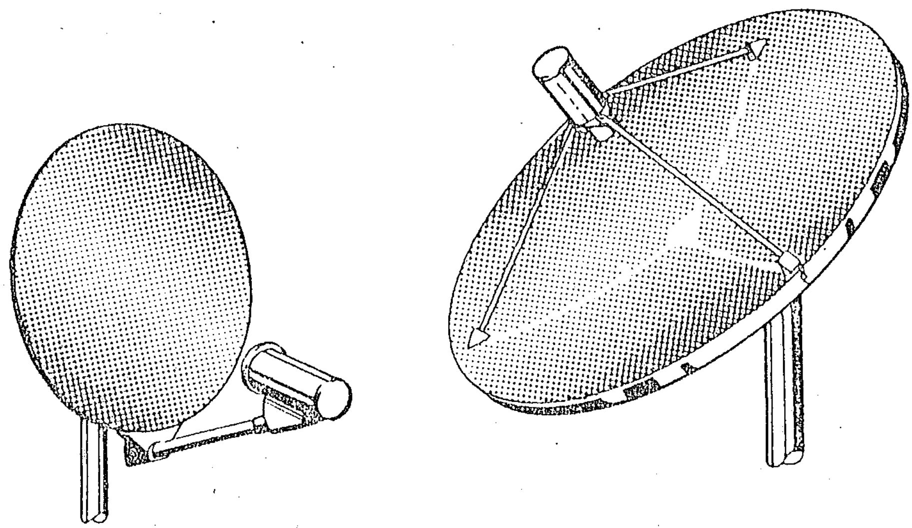


$|y| = \sqrt{4}Dx\ (f/D)$

$G_{(dBd)} \approx 10\log_{10}(6(D/\lambda^2))$

$\varphi_{3dB} \approx 70\lambda/D$

c



The first one is referred to as the PRIMARY FOCUS TYPE and is probably the best known. Some of its basic design formula are given inset with the drawing.

The CASSEGRAIN AERIAL is a more sophisticated type exibiting improved efficiency and easier LNA mounting at the centre of the reflective surface.

The OFFSET AERIAL shown in the diagram is expected to become widely used in the future as it can offer higher efficiency than the primary focus type. The reason for this lies in the comparitively large shadow that the LNB mount and the support rods throw onto the the reflective surface. This effect becomes more serious with relatively small dish sizes.

After considering all the factors involved we decided to adopt the PRIMARY FOCUS TYPE as this involved the simplest installation.

The concluding part of this section deals with the study of certain important parameters and terms which are vital to designing and confirming our reception system.

ANTENNA EFFICIENCY AND EFFECTIVE APERTURE AREA

For our dish which has a diameter of 3 meters, the physical area of interception of signal

$$A = \pi \times 1.5^2$$

$$= 2.25\pi$$

If we consider an input signal of power flux density 5 m W / m

Power recieved P_R = 5 x 2.25 mW

This is because every dish has an EFFECTIVE APERTURE AREA A which is approximately equal to 0.6 x A

The antenna efficiency $= \frac{A_E}{A_P}$

A

It must be remembered that gain of the antenna is based on this effective area.

$$\text{Gain of the antenna} = \frac{4\pi A_E}{\lambda^2}$$

PATH LOSS - L

The theoretical path loss L relevant to a line of sight link between 2 stations spaced d kms and operating in the frequency range of 3 - 10 GHz is approximated by

$$L = 114 + 20 \log_{10} d \quad \text{dB}$$

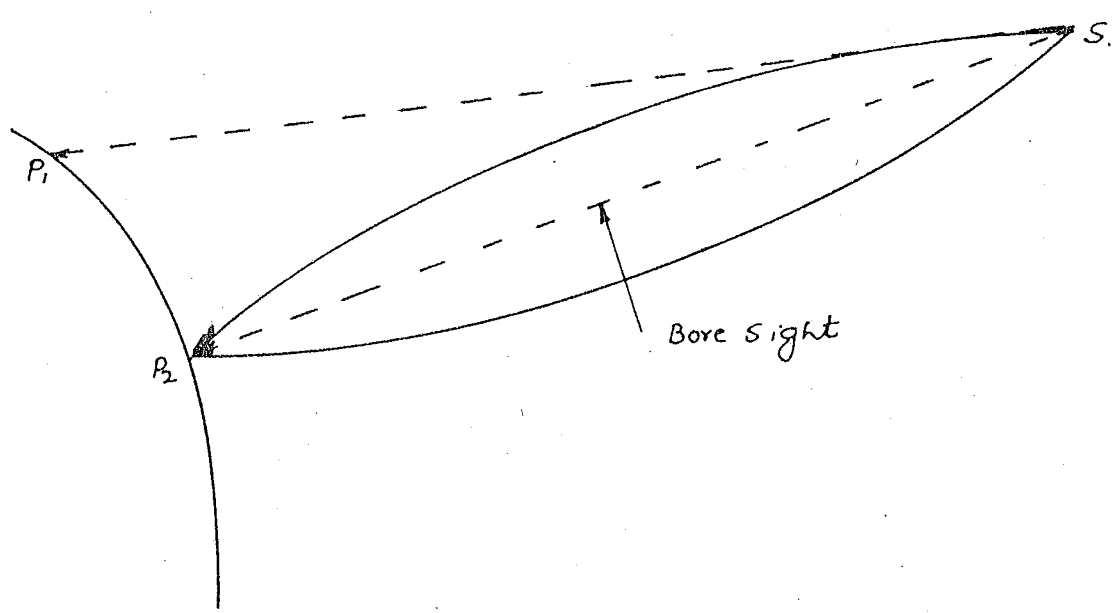
The figure 114 is an emperically established, sufficiently conservative factor that however DOES NOT include any additional attenuating influences such as heavy fog, rainfall, hail, passing aircraft of sudden disturbances in the relevant of the atmosphere.

Additional attenuation caused by adverse weather conditions may rise to as much as 0.6 dB/km. while satellite positioning errors may cause an even furthur decrease.

$$L = 114 + 20 \log 36{,}000$$

$$= 205 \text{ dB}$$

EIRP AND POWER RECEIVED



Consider a satellite S and 2 recieving stations P_1 and P_2 (P_2 is on the bore sight)

We have seen that gain of the antenna on any point away from the bore sight = $G(\theta, \phi)$

Power Recieved $P_R = P_t \times G(\theta, \phi) \times G \times L$

where

P_t	=	power transmitted
$G(\theta,\phi)$	=	gain at location P away from the bore sight
G	=	gain of the antenna $\left(\frac{4\pi A_E}{\lambda^2}\right)$
L	=	path loss

The factor P x $G(\theta, \phi)$ is called the EFFECTIVE ISOTROPIC RADIATED POWER (EIRP)

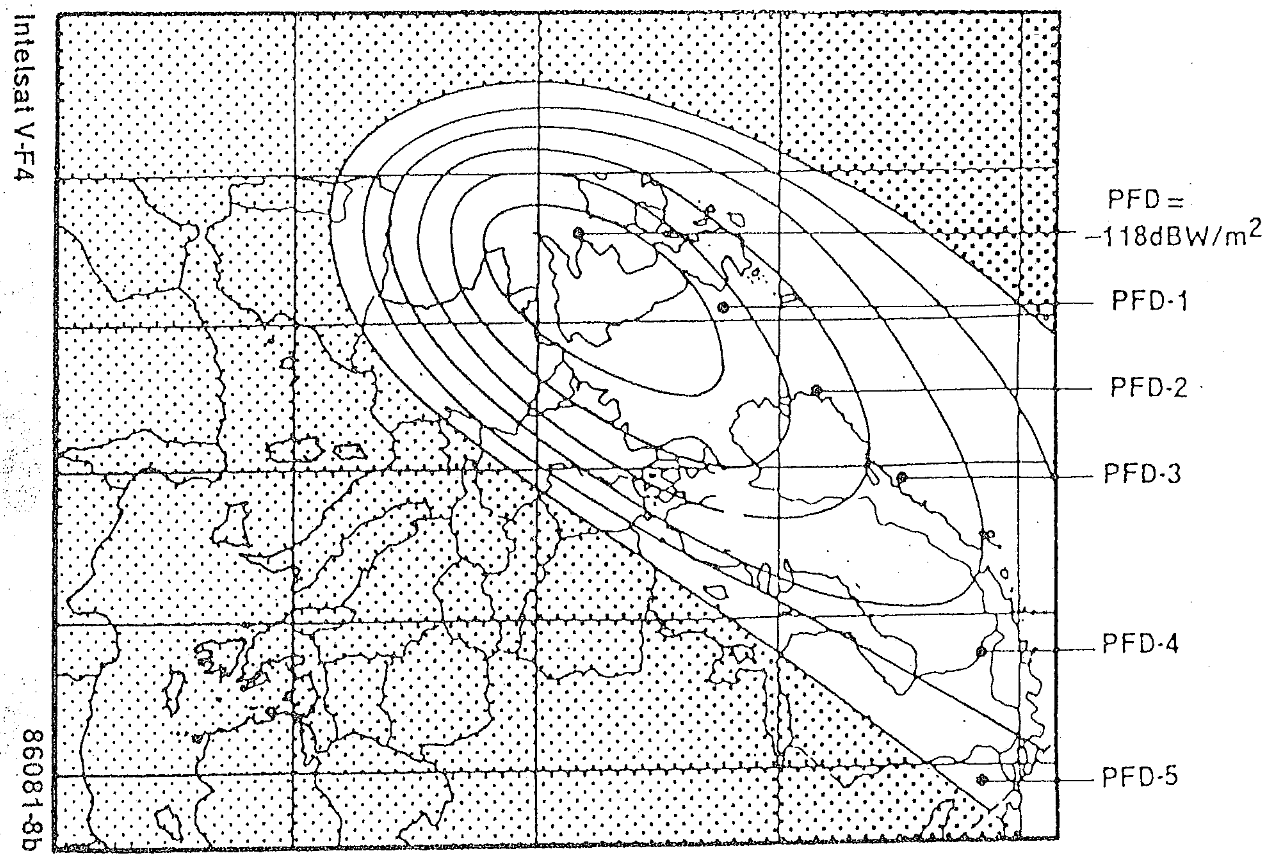
Receiver dish size is highly dependent on satellite EIRP.

The EIRP is a particular value for a particular satellite and ground station area. For example transmissions broadcast from INTELSAT VF-4 and collected at Bangalore have an EIRP value of 30 dBW.

POWER FLUX DENSITY PFD

On an effective surface of 1 m the satellite produces a power flux density (PFD) of:

$$PFD = G + EIRP - L \quad dB\ w/m$$



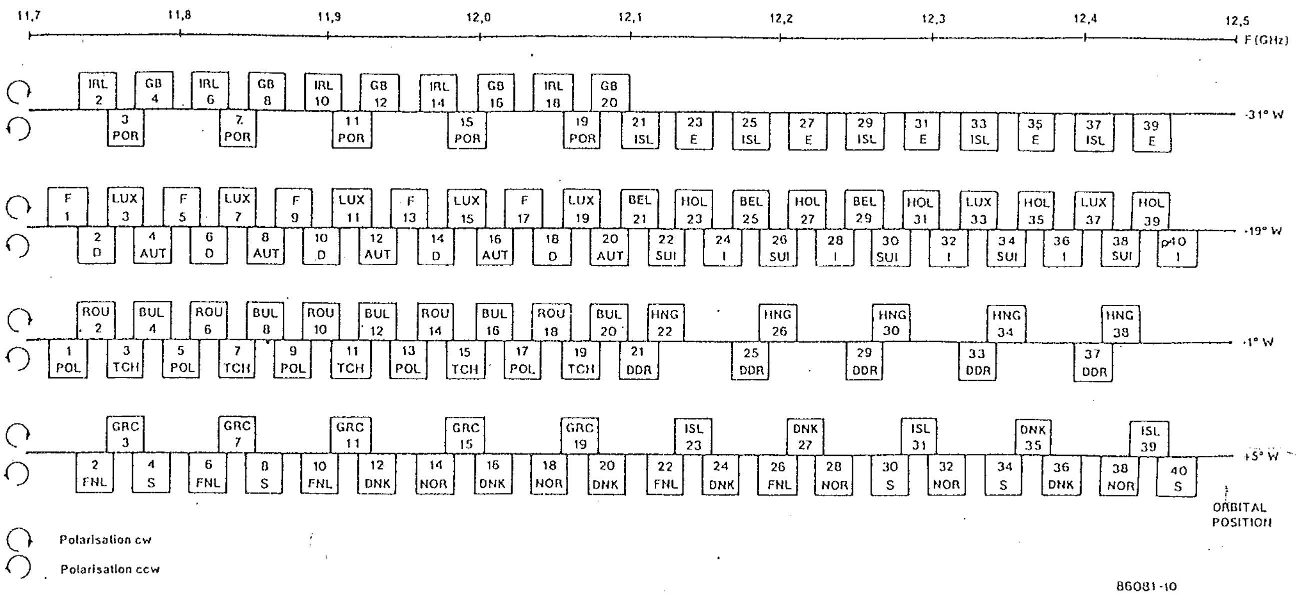
The PFD is a measure of relative signal strength in satellite reception technology and system planning. In the figure below PFD contours have been drawn for the elliptical beams produced by INTELSAT VF-4.

POLARIZATION

Any electromagnetic wave propagating in free space is said to have a particular polarization. If the electric field intensity variation is contained in a plane we get a linearly polarized wave. A wave transmitted by a dipole antenna is linearly polarized.

Consider 2 dipole antennas perpendicular to each other. If both transmit waves in phase, we get a linearly polarized wave at a direction of 45 to either of them but if the phase between them is adjusted to be 90 we get a circularly polarized wave. In a circularly polarized wave, the tip of the electric vector describes a circle. Most video signals transmitted are circularly polarized.

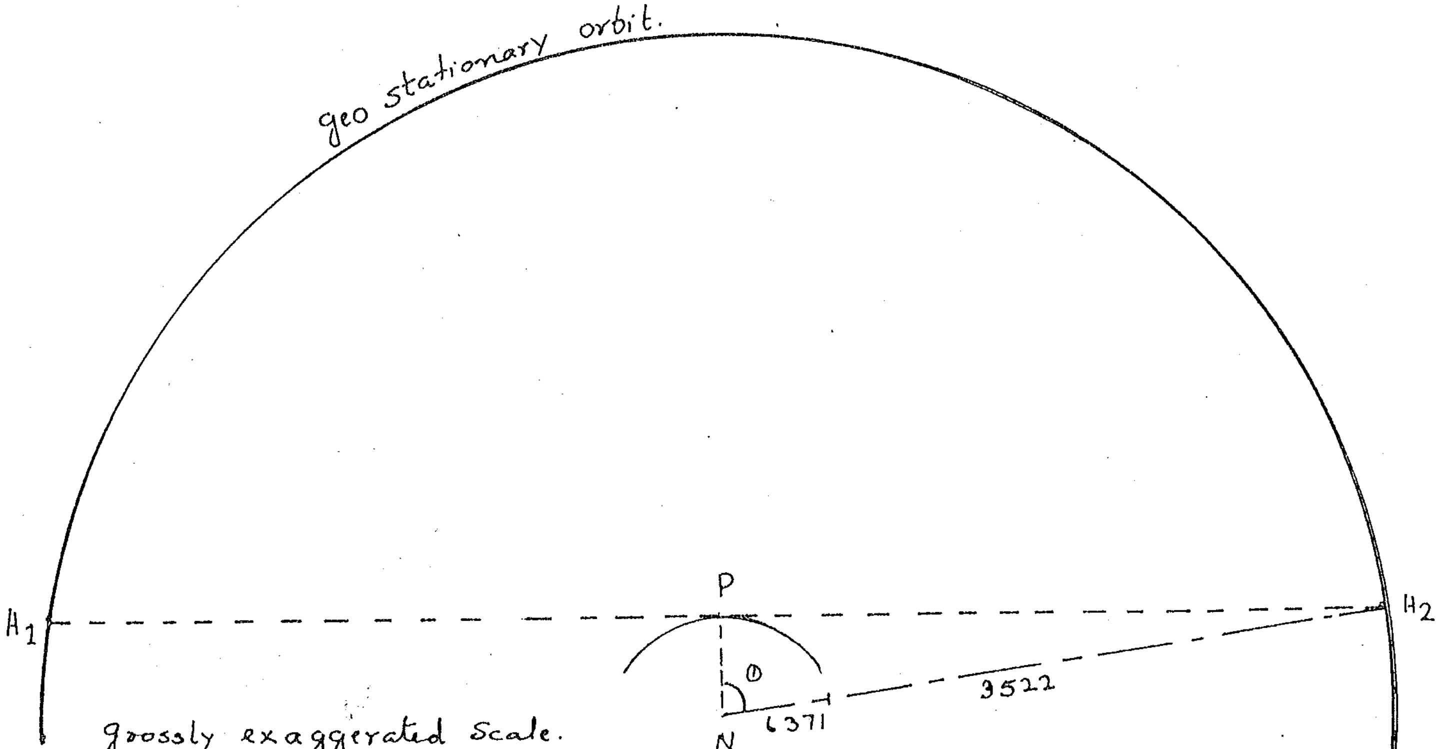
Depending on whether the phase shift is positive or negative we get a left handed or right handed circular polarization. The recieving antenna should be matched to this polarization or loss of signal will result.



SECTION 5

SATELLITE POINTING ANALYSIS

A detailed analysis of the satellite-earth system is necessary to furnish parameters for the dish mounting system. However, before doing so it is important to determine the limits of reception of our dish with respect to the horizon.



Consider our dish mounted at point P. The circle H H depicts the geo-stationary orbit. Limits of reception are obviously the horizon points H and H .

cos = 6371 / (6371 + 35822) = approx. 81

This is an extreme value and for sucessful reception the value of may be taken as 60 .

In this range (for a value of approx, 60) the following table givess the existing and planned geostationary satellite networks that will be available to us.

ORBITAL POSITION DEGREES EAST	NAME OF SATELLITE	COUNTRY	FREQUENCY BAND GHz
35	STATSIONAR - 2	USSR	4/5/6
35	STATSIONAR - D3	USSR	4/6
40	STATSIONAR - 12	USSR	4/5/6
45	STATSIONAR - 9	USSR	4/5/6
45	STATSIONAR - D4	USSR	4/6
53	MORE - 53	USSR	1/4/6
57	INTELSAT VF - 1	USA IT	4/6/11/14/1
60	INTELSAT VF - 7	USA IT	4/6/11/14/1
63	INTELSAT VF - 5	USA IT	4/6/11/14/1
64.5	MARECS - C	FRANCE	1/6/4

64.5	INMARSAT	UK	1/4/6
66	INTELSAT SERIES	USA IT	4/6/11/14/1
66.5	INMARSAT	UK	1/4/6
70	STW - 2	CHINA	4/6
73	MARECS	FRANCE	1/4/6
74	INSAT - 1B	INDIA	4/5/6
74	INSAT - 2C	INDIA	4/5/6
77	PALAPA - A2	INDONESIA	4/6
80	POTOK - 2	USSR	4
80	STATSIONAR - 1	USSR	4/5/6
80	STATSIONAR - 13	USSR	4/6
82.5/83	INSAT - 1D	INDIA	4/6
83	INSAT - 2A	INDIA	4/6
83	PALAPA - A1	INDONESIA	4/6
85/86	STATSIONAR - 3	USSR	4/5/6
85	STATSIONAR - D5	USSR	4/6
87.5	CHINASAT - 1	CHINA	4/6
90	STATSIONAR - 6	USSR	4/6
93.5	INSAT - 1C	INDIA	4/6
93.5/94	INSAT - 2B	INDIA	4/6
95	CSDRN	USSR	11/4
95/96.5	STATSIONAR - 14	USSR	4/6
98	CHINASAT - 3	CHINA	4/6
108	PALAPA - B1	INDONESIA	4/6
110.5	CHINASAT - 2	CHINA	4/6
113	PALAPA - B2	INDONESIA	4/6
118	PALAPA - B3	INDONESIA	4/6
125	STW - 1	CHINA	4/6

128	STATSIONAR - 15	USSR	4/5/6
128	STATSIONAR - D6	USSR	4/6
140	STATSIONAR - 7	USSR	4/6

SATELLITE POINTING ANALYSIS (contd) -THE MOUNTING SYSTEM

Our city of Bangalore lies approx. 80 east. We have seen that the physical limits of reception correspond to a value of about 60 . It is our desire to intercept transmission signals from the maximum number of satellites in this range of

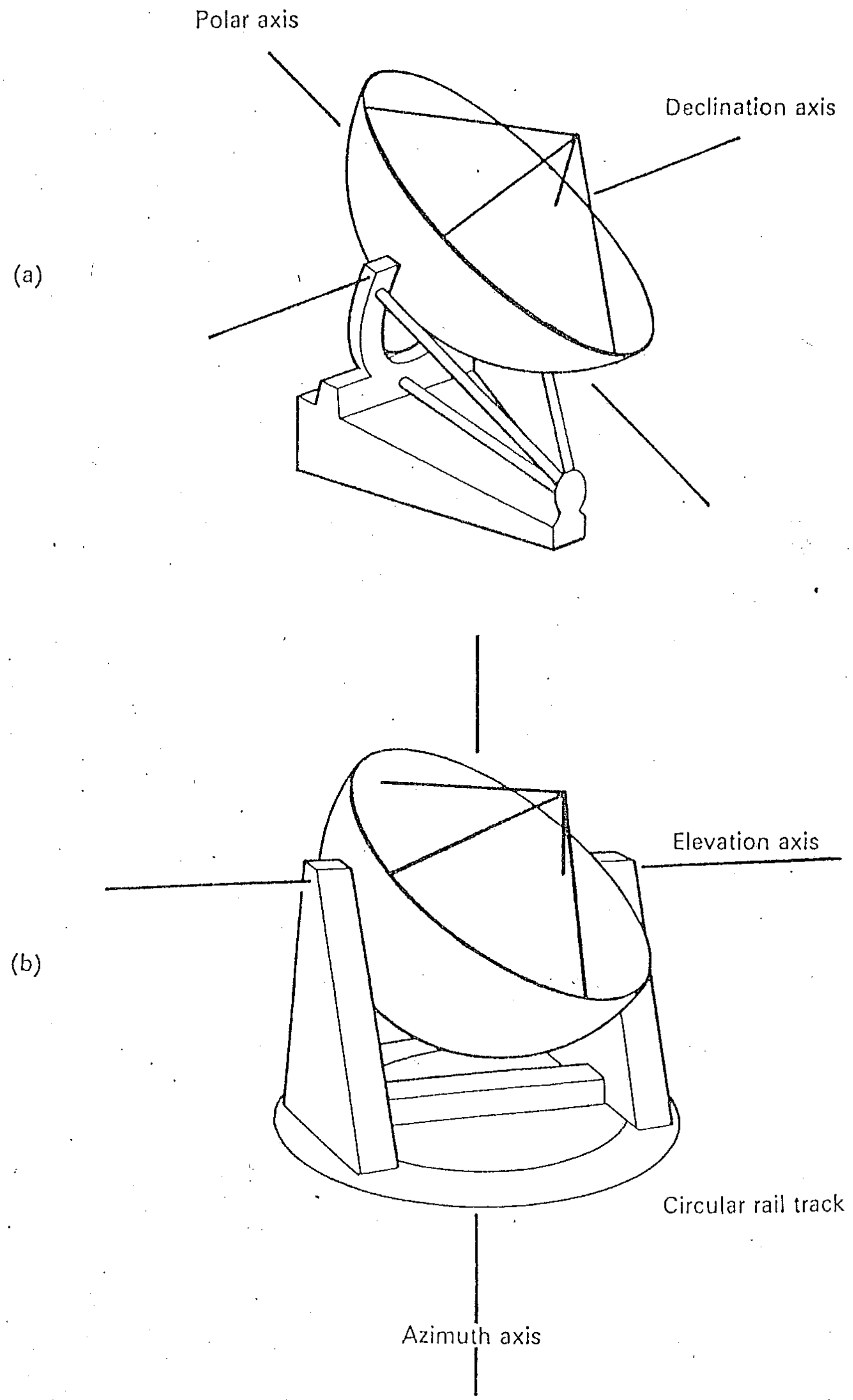
80 + 60 = 140 to 80 - 60 = 20 of longitude.

Any mounting system considered must be able to scan this + 60 longitudinally . Depending on the latitude of a particular place the receiving dish must be tilted by an appropiate amount towards the equator (geo-stationary orbit). This initial tilt is known as LATITUDE COMPENSATION (in our case ,our latitude = 13degrees).

However as is explained in the forthcoming section, these are not the only requirements. To scan from the ideal or overhead satellite (0 long.) to the extreme one (140 or 20 long.)a furthur variable tilt of upto 2.27 must be provided in addition to the latitude compensation.

Many mounting systems were investigated and certain decisive paramaters tabulated as shown below.

	AZ - EL	X - Y	POLAR	3-AXIS	DIFFEREN.
MECHANICAL STRTUCTURE REQUIRED	extremely heavy str. required	same as AZ - EL	comparit- ively much lighter	same as AZ - EL	same as AZ - EL
ATTAINABLE ACCURACY	high	high	high	high	high
RELATIVE COST	high	high	low	high	high
SKY COV- ERAGE POSSIBLE	v.high	high	low	high	high



53. Radio-telescope mounts. Some small radio telescopes use the polar mount (a), which is usual for optical telescopes, but most use the altitude-azimuth mount (b), which can carry larger and heavier structures with less distortion

It must be mentioned here that the 2 important considerations for our project were

1) COST

2) MOBILITY OF THE GROUND STATION

The table shows that the polar mount is the only one feasible when taking the above 2 factors into consideration. However the classical polar mount is unable to meet the required 2.27 fluctation.

Our mounting system is a simple solution to the problem. Though nothing but an improved version of the typical polar mount, it does fulfil all the necessary requirements.

SATELLITE POINTING ANALYSIS (contd)

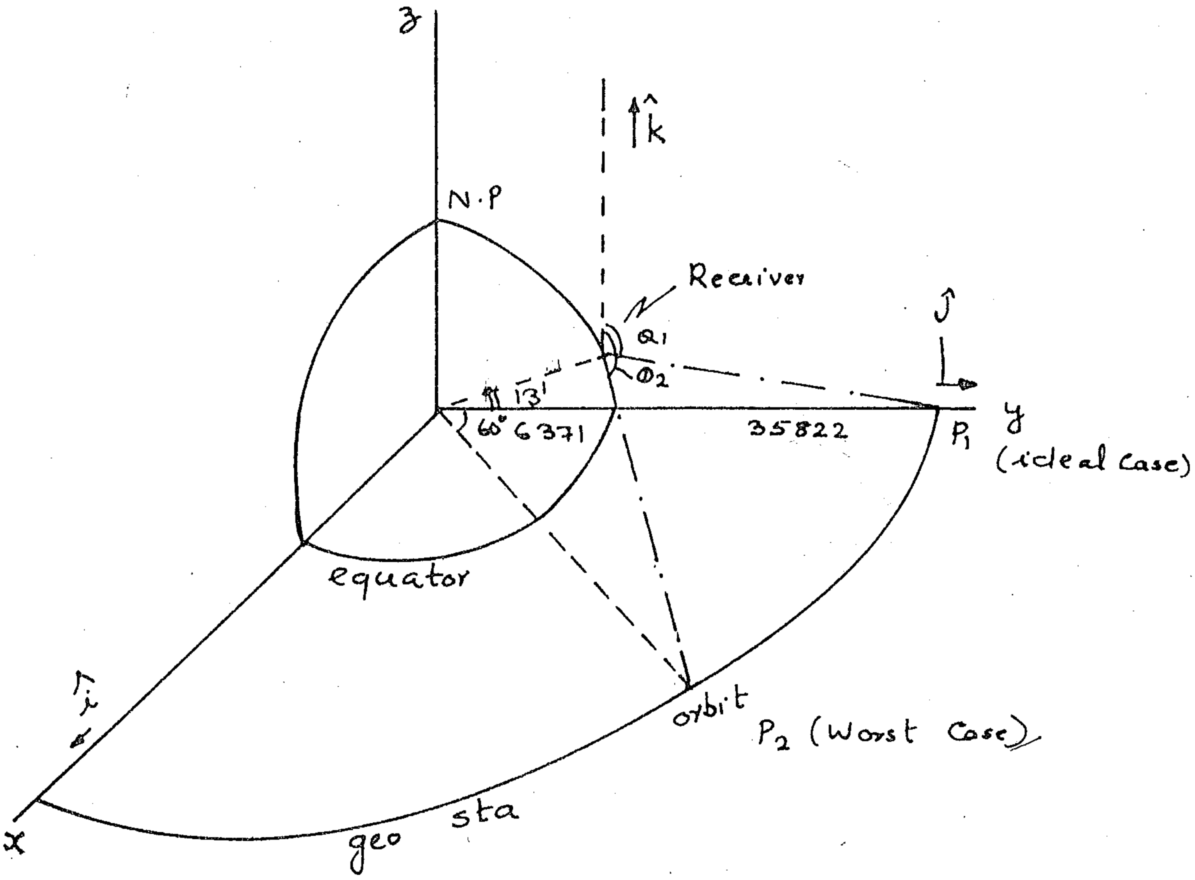
If the ground station was situated precisely on the equator then the dish antenna would point directly upwards. However our dish is to be located at Bangalore whose latitude is 13 N. (represented in the diagram by point A). Hence our first consideration is a latitude compensation of 13 .

Consider a satellite at point P . (overhead)

OA = approx. 6400 kms.

OP = approx. 6400 + 36000 = 42400 kms.

OP = 42400 j


z
k̂
N.P
Receiver
a1
a2
13'
60°
6371
35822
ĵ
y
P1
(ideal case)
equator
î
orbit
P2 (Worst Case)
x
geo sta

$OA = (6400 \cos 13)\ j + (6400 \sin 13)\ k$

$OA = 6200\ j + 1440\ k$

$AP = OP - OA$

$AP = 42400\ j - (6200j + 1440k)$

$AP = 36200\ j - 1440\ k$

$AP = 36228.63$

Now vector product

$$k\ AP = AP \cos$$

$$k\ (36200\ j - 1440\ k) = 36228.63 \cos$$

$$\text{or } \cos = \frac{-1440}{36{,}228.63}$$

$$= 92.27$$

Consider the satellite at position P (+ 60 longitude)

$OP = 42{,}400$

$OP = (42{,}400 \sin 60)\ i + (42{,}400 \cos 60)\ j$

$OP = 36{,}719\ i + 21{,}200\ j$

$OA = (6400 \cos 13)\ j + (6400 \sin 13)\ k$

$OA = 6200\ j + 1440\ k$

$AP = OP - OA$

$AP = 36{,}719\ i + 21{,}200\ j - (6200j + 1440k)$

$AP = 39{,}767.71$

Now vector product

k.AP = AP cos

k (36,719i + 15,200j - 1440k) = 39,767.71 cos

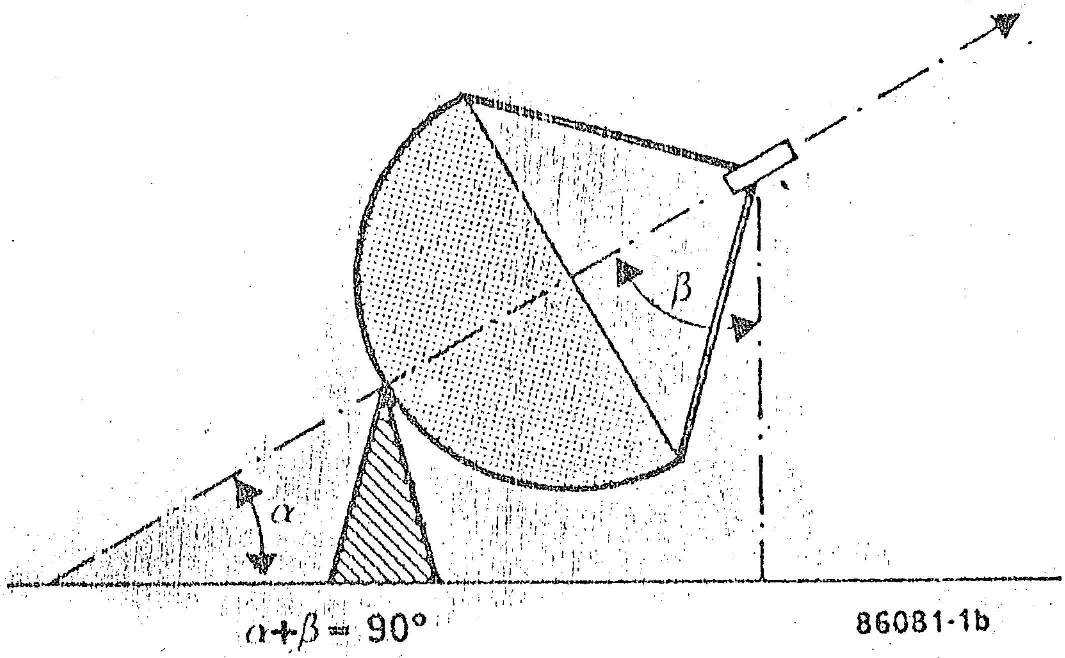
$$\cos = \frac{-1440}{39767.71}$$

or = 92.07

It is hence seen that even after the initial compensation of 13 , a furthur tilt of (92.27 - 90) = 2.27 must be provided with some provision for a fluctuation of (92.27 - 92.07) = 0.2

Thus we see that given a specific orbital position, the reciever dish elevation angle will need to be established for the relevant latitude of the reciever location within the satellites service area.

Thus there exists a complex relationship between orbital position, longitude, azimuth and the angle of elevation and this has been taken into consideration as the bases for the design of our polar mount.



SECTION 6

To confirm an acceptable signal : noise ratio.

ASSUME A DISH DIAMETER OF 3 METRES

Our working frequency = 4 GHz

Wavelength = 30 = 7.5 cms.
4

Consider transmissions broadcast from INTELSAT VF-4 and collected at Bangalore . EIRP = 30 dBw or 60 dBm

Gain = 4 A

= 4 x 0.6 x x (1.5)
(7.5)

= approx. 40 dB

Path Loss =

4 R

= 7.5

4 x 36,000

= approx. - 197 dB

Signal Recieved = EIRP - Path loss - Gain

= 60 - 197 + 40

= - 97 dBm

Noise power recieved = K T B

where

K is the Boltzmann's constant = 1.38 x 10 W sec/ K

T is the system niose temp. = T + T

= 300 K

B is the Band Width = 5 MHz

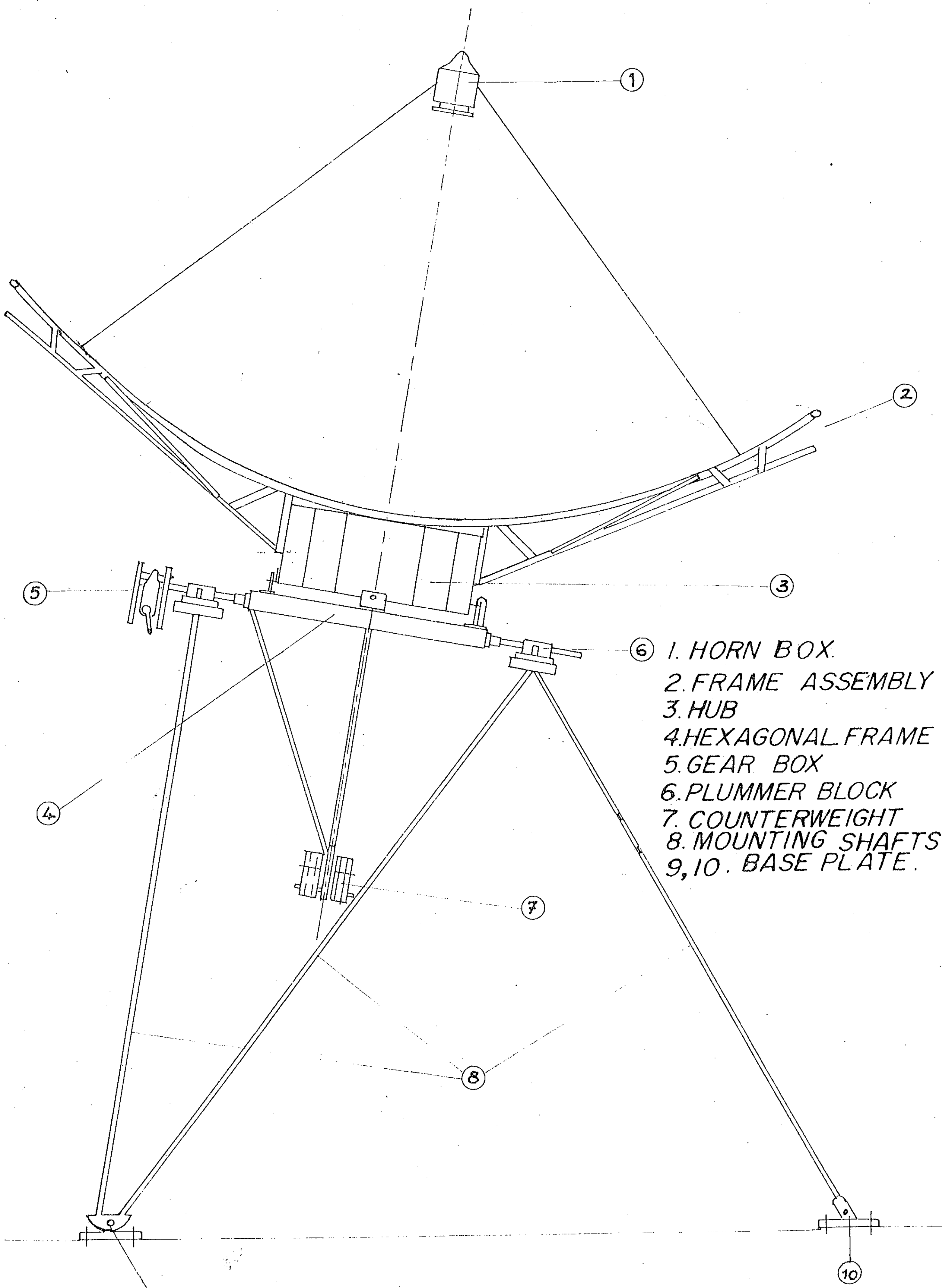
Noise power recieved = - 110 dBm

SIGNAL : NOISE = 13 dBm

which is an acceptable figure.

HENCE WE DESIGN THE DISH DIAMETER TO BE 3 METRES.

Note that for an EIRP of less than 25 dBw, the ratio will not be acceptable (i.e Signal : Noise $<$ 20) and hence reception will not be successful.


1
2
3
4
5
6
7
8
10
1. HORN BOX.
2. FRAME ASSEMBLY
3. HUB
4. HEXAGONAL FRAME
5. GEAR BOX
6. PLUMMER BLOCK
7. COUNTERWEIGHT
8. MOUNTING SHAFTS
9, 10. BASE PLATE.

SECTION 7

DISH ANALYSIS AND SPECIFICATIONS

Focal length	=	900 mm.
F/D ratio	=	0.3
Dish Gain at 4 GHz	=	approx. 40 dB
Surface Accuracy	=	1 mm. RMS
Dish Efficiency	=	65 %

WEIGHT

A) DISH

1)	16 Aluminium Frames	=	28.8 kg.
2)	Outer pipe	=	3.2 kg.
3)	Inner pipe	=	1.6 kg.
4)	Weight of 16 Al strips	=	1.92 kg.
5)	Weight of 16 perforated strips	=	4 kg.
6)	Miscellaneous (nuts, bolts, Al attachments etc)	=	1 kg.
7)	Weight of Horn and its supports	=	2 kg.
	Total weight of Dish	=	42.52 kg.
B)	Hexagonal Frame	=	18.929 kg.
C)	Hub frame	=	9 kgs.
	Welded plates inside hub	=	3.4 kg.

Hub top plates	=	8.36 kg.
Total weight of hub	=	20.76 kg.
D) Shaft	=	6.6 kg.
E) Counterweight Support	=	5 kgs.
F) Counterweight	=	40 kgs.

Percentage of Perforated Area on the Dish

A square strip of side 13.8 cm. was used and the percentage of the perforated area was found to be about 47.5 % to the total area of the dish.

WIND LOADS

Wind pressure is given by relation

$p = 0.006*v$

where, P = pressure in kg/square meters

V = wind velocity in km/hr

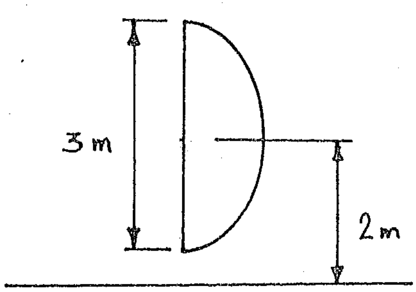
For 50km/hr velocity $P = 15kg/m^2$ (A)

80km/hr velocity $P = 38.4/m^2$ (B)

The wind loads are acting on antenna and mount structure.

Case 1: Wind acting on Antenna in horizontal position.

Area,A# = 7 sq.m.



Force F, (A) 7 x 15 = 105 kg

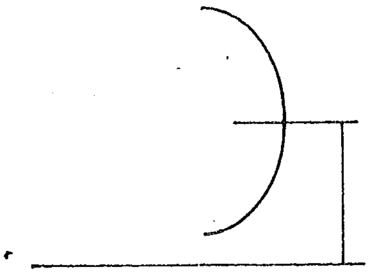
(B) 7 x 38.4 = 269 kg

Horizontal load on Bearings

For (A) - load on each Bearing =53 kg

(B) - load on each Bearing =135 kg

Tilting moment on foundation-clamp down bolts

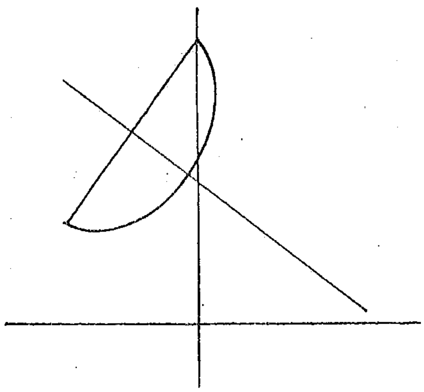


(A) 105 x 2 = 210 kgm

(B) 270 x 2 = 540 kgm

Case II

Wind acting on antenna at 45 degrees



Area of ellipse = ab

Area = 4.95 sq.m.

say = 5 sq.m.

Base area negligible

Force (A) 5 x 15 = 75 kgm

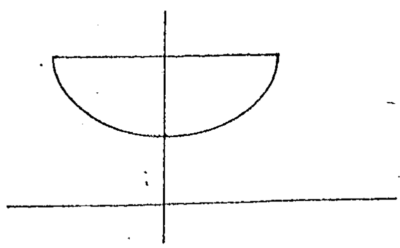
(B) 5 x 38.4 = 192 kgm

Horizontal load on Bearing

(A) 50 kmph = 38 kgm

(B) 80 " = 96 kgm

Case III

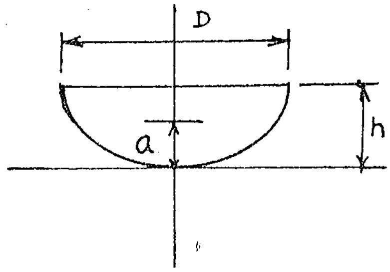


(A) 1.5 x 15 = 22.5 kgm

(B) 1.5 x 38.4 = 57.6 kgm

$F/D = 0.3$

$f = 900$ mm

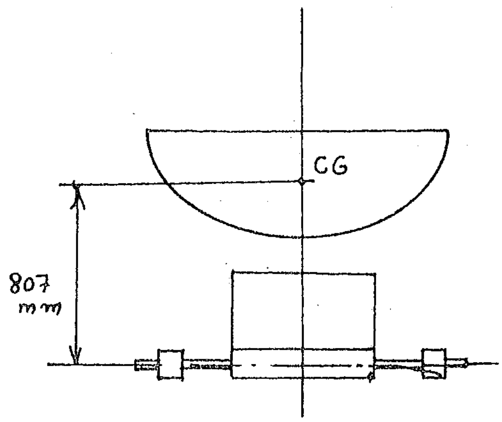


Centre of gravity $= a = \frac{3h}{5}$

$= \frac{3 \times 625}{5}$

$= 375$ mm

For the complete parabolic area, the C.G. is on the centre line or axis.



C.G from axis $= 375 + X$

$= 375 + 432$

$= 807$ mm

Combination loads on Antenna mount bearings

Gravity Load on Bearing

Weight of dish	=	42.52
Weight of hexagonal frame	=	18.93
Weight of hub	=	20.76
Weight of shaft	=	6.6
Weight of U-support	=	5.0

Weight of counterweight	=	40.0
TOTAL	=	133.81

The main loads on the bearing are due to wind and gravity.

Fg = gravity load

FW = Force for wind 80 km/hr

$$Fr = \sqrt{Fg^2 + Fw^2}$$

Fg = 134 kg

Fg on each bearing = 134/2

= 67 kg

Fw = At 80 km/hr = 38.4 kg

Area of Dish at Horizontal position = 7 sq.m.

= (38.4 x 7)/2

= 135 kg per bearing

$$Fr = \sqrt{67^2 + 135^2}$$

= 151 kg

Axial load on bearing = Antenna weight + fr

= 151 + 134 = 285 kg

Bearing used T2306 - Static load - 1020 kg

Dynamic load- 2450 kg

Maximum speed- 8500 rpm

Factor of safety

for Dynamic load, 2450/285= 8 times.

for Static load, 1020/285= 4 times.

This factor of safety is based on the assumption that the antenna reflecting area is totally wind resistant. But,since the surface is covered by perforated sheet which is only 50 % wind resistant, the factor of safety will be twice better.

SECTION 7

FABRICATION DETAILS

The aim of this project was to fabricate a dish antenna having a diameter of 3 metres. The fabrication involved making of many components which are as follows:

1. THE TEMPLATE

2. THE DISH

consisting of sixteen aluminium frames and aluminium perforated mesh.

3. THE HUB AND HEXAGONAL BASE FRAME

4. THE TRIPOD MOUNT

The final stage involved assembly of the components and also the inspection of the dish for surface accuracy.

1. THE TEMPLATE:

A mild steel plate of length 1500 mm. and width 600 mm. having a thickness of 2mm., without kinks and dimples or scratches was machine cut to get a 90 degree edge. Markings were made on this plate with respect to the valuesd obtained from the computer (which is attached). The X-Y co-ordinates were marked on this plate and the points joining these co-ordinates formed the parabola. Care was taken to obtain a uniform curve.

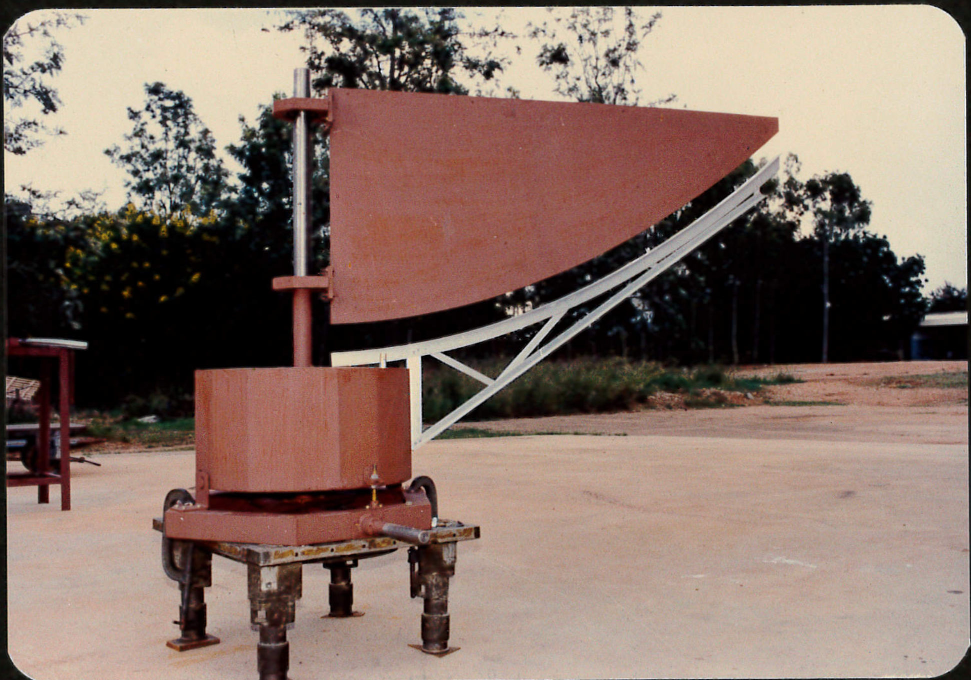
The plate was then accurately cut along this curve and then filed for a good finish. To provide a facility of rotation to this plate, two accurate bearings were attached to it. These bearings were selected in such a way as to suit the specifications of a central shaft to which they were hooked.

THE FRAME:

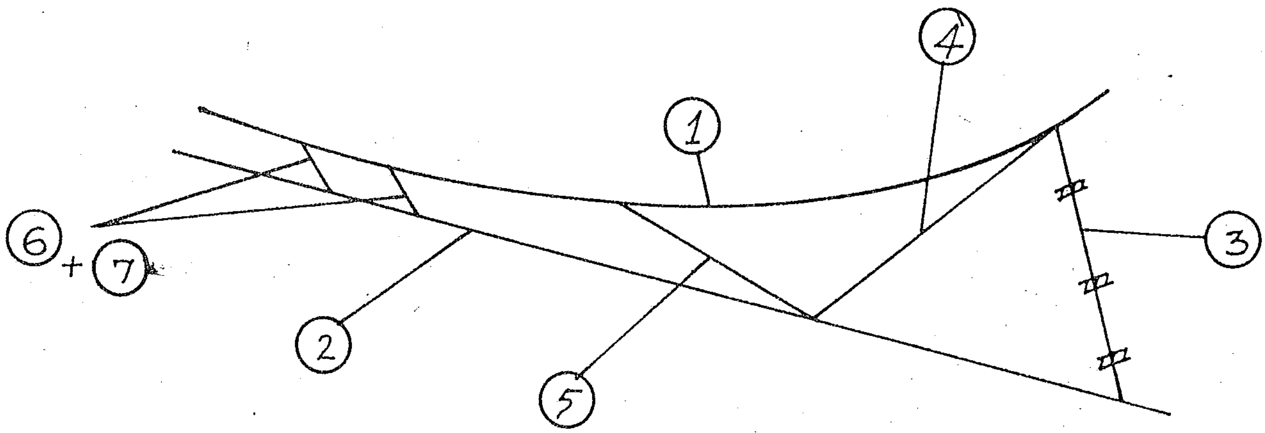
Sixteen identical aluminium T-sections of length and thickness 3mm were taken. These T-sections, also called rib trusses were all fabricated on one shop jig. They were first cold formed to the parabolic profile, (with reference to the template made earlier) to the required accuracy. Adequate care was taken to see that there was no twist in any of the T-sections.

To provide a support to the cold- formed T-section, a frame consisting of aluminium L-angles of varying thickness and lengths was fabricated. One parabolic shaped T-section along with another straight T-section and five aluminium L-angles formed part of a frame. The following figure gives details of one typical frame.

To maintain a high degree of accuracy while assembling and also to facilitate the assembly process itself, a jig/fixture of full size was prepared. This provides for easy and accrate positioning of the different components



which were assembled using pop-rivets.



INDEX FOR FIGURE.

(1) BENT ALUMINIUM T-SECTION OF THICKNESS 3 mm AND LENGTH 1600 MM

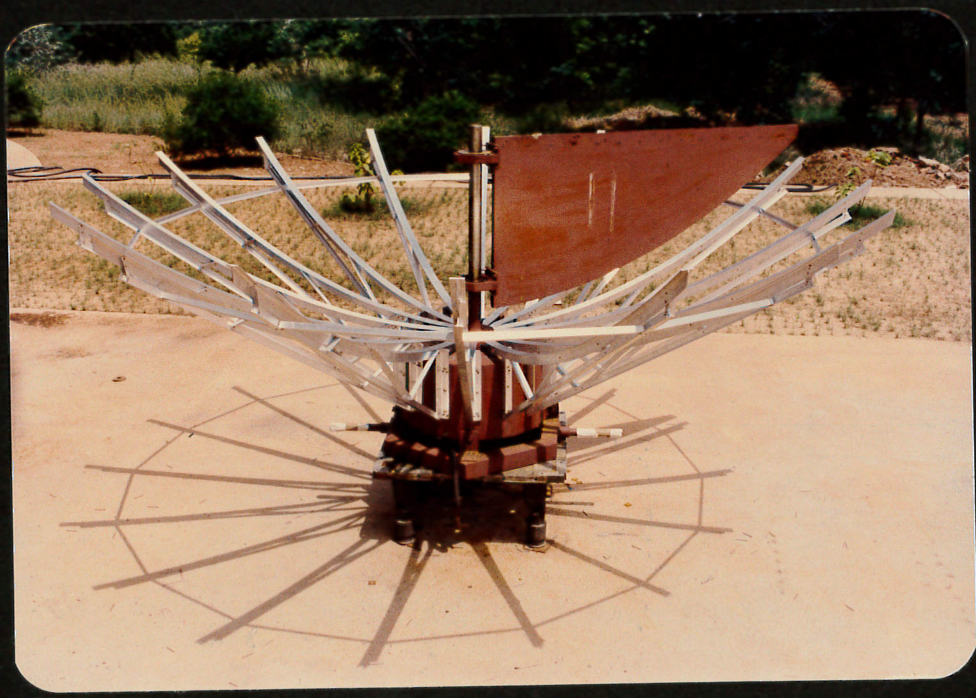
(2)ALUMINIUM T-SECTION OF THICKNESS 2 mm AND LENGTH 1360 mm

(3)ALUMINIUM L-ANGLE OF THICKNESS 4 mm AND LENGTH 280 mm

(4)ALUMINIUM L-ANGLE OF THICKNESS 3 mm AND LENGTH 250 mm

(5)ALUMINIUM L-ANGLE OF THICKNESS 2 mm AND LENGTH 350 mm

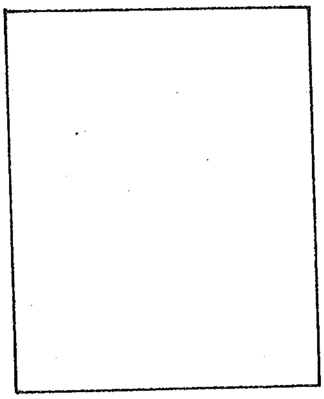
(6) and (7) ALUMINIUM L-ANGLE OF THICKNESS 1.5 mm AND LENGTH 70 mm

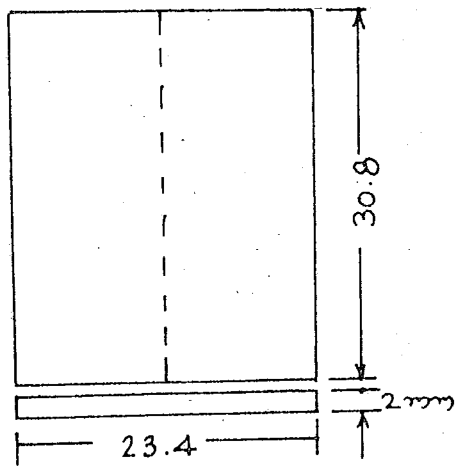


All the sixteen frames were then polished using steel wool to remove any minor imperfections and then kept aside for final assembly.

2. THE HUB

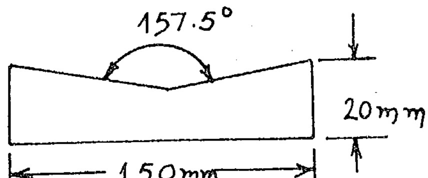
The hub consisted of a sixteen sided polygon, obtained by bending 8 plates, each of 30.8 cm long and width 23.4 cm, 2 mm thick as shown in the diagram. These plates were cut, (using a shearing machine) from a large master plate of length 2.43 mts and breadth 1.22 mts.

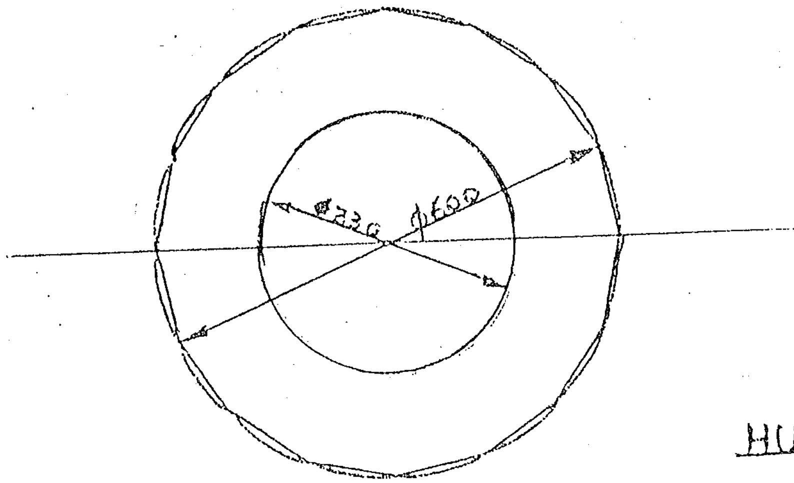




This plate is bent at its centre on a bending machine to an angle of 157.5 degrees. These 8 plates were used to form the required to form the required polygon. A jig as shown in figure provided the necessary guide while bending the plates in the centre and also in joining two adjacent plates while forming the polygon during welding.

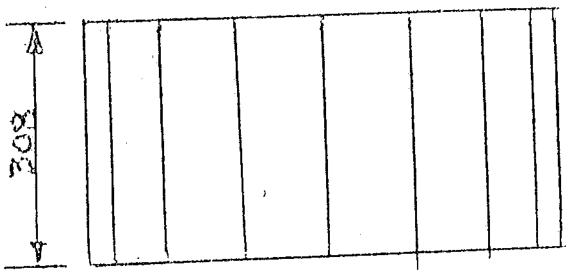
To provide a cover for the above at the top and bottom, two plates were made. These plates were first cut in the form of a circle of diam. 60 cms., each plate having a





HUB.

SCALE 1:10

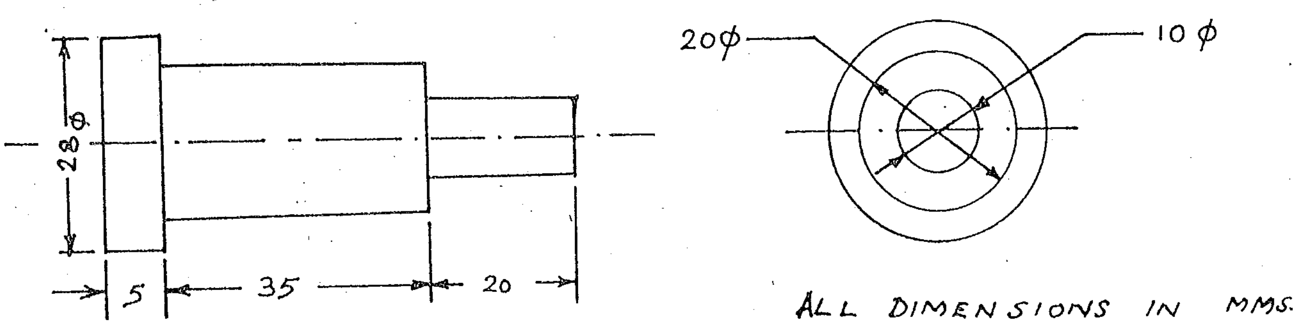


thickness of 3 mms, 16 sides were then marked within the circle and cut at these markings using a shearing machine. On these two circular plates, a hole of diam. 330 mms. was cut at the centre. The plates were then placed in their respective positions, i.e. at the top and bottom of the hub and tacked accordingly.

Next, two plates of thickness 20 mm and length 115 mm, width 95 mm were placed at the bottom of the hub on two directly opposite sides and welded firmly. These two plates were provided to act as a support for the two sholder bolts about which the hub pivots to an angle of +2 degrees. Care was taken to see that the holes were in the same axis.

The next step involved the manufacture of the shoulder bolt. This part was very important as the whole weight of the hub, with the dish pivoted about this bolt. The diagram of the bolt showing its details is given here.

SHOULDER BOLT - SCALE 1:1

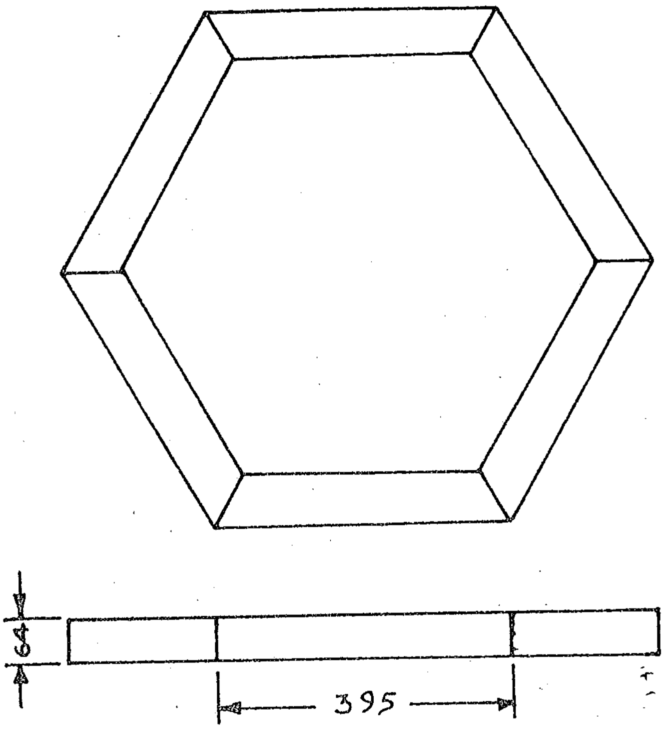


RIGHT HAND THREAD M10x1.5

To provide support for the hub and the shoulder bolts, a hexagonal frame was made. The hub rests on this frame by means of an L-shaped plate. This plate connecting the hub and the hexagonal frame is so designed as to provide a means of tilting of the hub by about 2 degrees.

The frame was made of six numbers mild steel L-angles of size 64 mm by 64 mm (6 mm thick) and 395 mm long. These six pieces were then welded together in the form of a hexagon. This comprised the hexagonal frame. Across two opposite sides of the frame, a flat mild steel plate was welded, providing the base for the central shaft on which the template was fixed. The diagram of the frame is shown below:

On this frame,two holes of diam. 30 mm were drilled on opposite sides. A shaft of diam. 30 mms. passes through these two holes, the length of shaft being 1200 mm. To accommodate this shaft and also to support for it, two collars of diam. 45 mm each were provided. These collars are welded on to two plates which are in turn screwed on to the frame on opposite sides. The shaft passes through these collars throughout the length of the frame .



The hub was then fitted on to this frame by means of an L-shaped plate in such a way as to include a provision of tilt to it.

3. THE TRIPOD MOUNT:

The hub with the frames attached, and the hexagonal frame were mounted at a height of 2.12 mts. to facilitate tilting of the dish to point towards horizon. The tripod mount mainly consisted of five numbers of mild steel pipes each of diameter 50 mm.

Basically, the mounting consisted of five pipes, of these two pipes were of length 2.61 mts. and two other pipes of length 2.56 mtrs. The fifth pipe was cut to a length of 2.21 mts. This pipe was then cut into two parts, one part of length .33 mts. and the other part 1.88 mts.

This procedure was adopted to fit a turnbuckle . The turnbuckle was attached to the two ends of the pipe by means of two collars of diam. 49.75 mms. each. This turnbuckle arrangement was provided so that the whole mounting along with the dish could be tilted and locked at any desirable latitude. The five pipes comprising the mounting were then welded to a channel. The channel was placed at an angle of 13 degrees to the horizontal, since the latitude of Bangalore is 13 degrees North. Latitude depends on the place and to accommodate this change, the five pipes have been provided with a pivoting facility at the base. On both sides of the channel the two pipes of dimensions 2.61 meters and 2.56 meters. converge in the shape of a V, where they are welded together. This joint is then covered with a box-like structure having a flat plate as its base. This flat plate sits on a forked hinge which pivots about a shoulder bolt.

Through this hinge, a hole is drilled of diameter 19 mm to accommodate a shoulder bolt. This hinge sits on a curved support of height of 75 mm. The support consists of a base plate of 50 mm square and has a rounded top. Through the centre of this support, a slot is provided of depth 38.1 mm and width 16 mm. This slot seats the hinge by means of the shoulder bolt. Similarly two such hinges were made. Each of these hinges were welded on to a bottom support plate of length 198 mm ,width 210 mm and a thickness of 17 mm.

On this bottom plate, four tapped holes were made and suitable screws provided means for fine levelling of the dish and also to accommodate unevenness in the surface on which the dish would be installed.

On the third side, i.e. the side facing the channel, the pipe of length 2.21 mts. was welded at one end to the channel and at the other end it was hinged on to a flat plate and fork of similar dimensions as discussed earlier. To facilitate a tilt in just one direction at a time, the axes of all the three hinges faced the same direction. This particular pipe also accommodated the turnbuckle which has been discussded earlier. Thus we see that all the five pipes sit on forked hinges and their position can be adjusted accordingly, and since the dish sits on this arrangement of pipe its position is also adjusted.

4. THE FOCUS

The focal length for the dish under consideration was calculated as 900 mm. The components to be placed at the focus were the feed horn and the RF part of the receiver. These were housed in a fibre glass box. This box was supported at the required position by means of a quadripod - a four-legged mont. four aluminium I-sections formed the legs of the quadripod. The I-sections were fixed suitably on the frame of the dish.

5. THE ASSEMBLY

Assembling the different parts of the antenna, made up the final stage of the project wherein a very high degree of accuracy was maintained. To ensure this and also to maintain a definite chronology of events, (used in this context because of the number of parts involved) in so far as the assembly was concerned, the assembly was carried out maintaining pre-defined steps.

The first step involved the assembling of the dish. This was done by screwing on each of the sixteen aluminium frames on to each of the sixteen sides of the hub. Each frame was first set correctly in its respective position. To assist in the accurate setting of the position of each of each frame on to the hub, the template (that was earlier used in the cold forming of each frame) was taken and attached to a central shaft of diam. 50 mm. This shaft was standing upright to the hexagonal frame, at its centre by means of four screws that were attached to a rectangular flat plane that ran from one side of the hexagonal frame to the other. The height of this shaft was about 1.2 mts. The template was attached to this shaft, with its curved surface facing downwards, by means of two bearings so that it could rotate about this central shaft through a total angle of 360 degrees. This facility was provided so that the template could be rotated and locked at any desirable angle. In this particular case, the template was rotated and locked at intervals of 22.5 degrees, since there were sixteen frames.

A theodolite was used to determine the exact position of the hub and central shaft. The thedolite was used to check and set accurately the position of the template after each rotation. Once the template was set at 22.5 degrees and locked, one frame was placed on one side of the hub and its exact position was set in accordance with the template. This was done by checking the curve of the frame with the curve of the template. The distance between the curved surface of the template and the top curved surface of the frame was fixed at 79 mm throughout. This distance was checked accurately by using two spacers one in the middle and one at the end made of brass. After this, the frame was fixed by drilling three holes of diam. 5 mm each, on the sides of the hub and then was screwed on to the hub in that particular position.

To allow the frames to possess a very small amount leverage, each frame is provided with a set of three grub screws, which allow the frames to deviate very slightly from their set position as and when required. This arrangement was necessary to accommodate any variation in the hub, as machining of the hub could not be carried out because the metal sheet used in making the hub was of a very thin gauge. To ensure that the position of each frame does not alter appreciably and also to provide a support to the lower end of the frame, a hexagonal bolt with a slot in the middle, was welded on to the top surface of the hub, under each frame. This was done in such a way that the lower vertical part of each frame set in the slot provided by each hexagonal bolt.

Thus adopting a similar procedure all sixteen frames were attached to the hub.

The next step dealt with providing a circumferential support to the dish. This was done by means of a circle. Each pipe had a length of 3.14 meters. and a diameter of 231.7mm. These pipes were then bent gradually on a bending machine in such a way as to form a circle when riveted together. This circular pipe was then attached to the ends of each frame by a process of pop-riveting which has been explained earlier. This pipe now formed the circumference of the dish which came to about 9.42 meters.

The surface accuracy of the dish was determined by mapping the surface of the dish by making X-Y coordinate measurements at number of points and fitting a best-fit paraboloid to these points. A theodolite was used to check and fix the precise position of the central shaft about which the template rotated. The position of the shaft was set to an accuracy of a few microns. Next, markings were made on the template at intervals of 100 mm. The template was then fixed over a frame and locked in that position. To check the surface accuracy of each frame an LVDT (Linear Variable Differential Transducer) was used. The LVDT is analogous of a dial indicator. The LVDT probe's movements are read on a digital display unit. (The LVDT and the

16 OCTOBER 86

TESAMETER READINGS - REFERENCE FRAME :

01)	625.0 + 79	=	704
02)	620.0 + 80	=	700
03)	612.5 + 79.5	=	692
04)	598.0 + 79.0	=	677
05)	579.5 + 79.0	=	658.5
06)	554.0 + 79.0	=	633
07)	523.0 + 79.0	=	602
08)	486.5 + 79.5	=	566
09)	445.0 + 79.0	=	524
10)	398.5 + 79.5	=	478
11)	345.0 + 79.5	=	424.5
12)	286.0 + 79.5	=	365.5
13)	223.5 + 80.0	=	303.5
14)	154.5 + 80.0	=	234.5
15)	80.5 + 80.0	=	160.5
16)	0 + 80.5	=	80.5

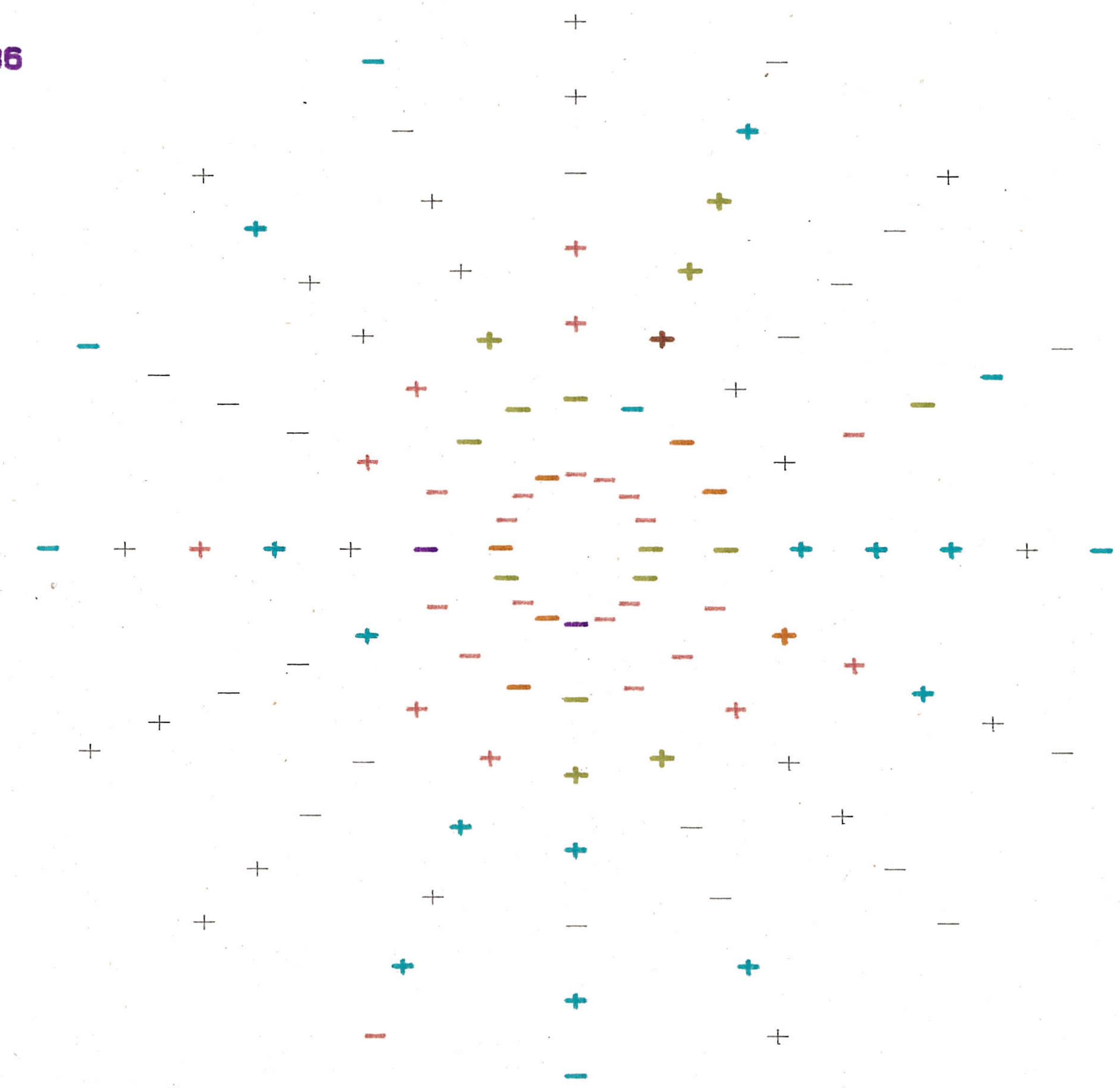
TESAMETER READINGS:

16 OCTOBER 86

	1400	1200	1000	800	600	400	200
01	+060	-165	+230	+330	+330	-242	-009
02	-460	-1030	-1820	-890	+485	-348	+436
03	-1740	-1430	-780	-420	-334	-730	+466
04	+190	+466	+560	+1230	+1409	+215	+905
05	+485	-012	-290	+070	+630	-079	+756
06	+150	-630	-807	-250	+156	-532	-230
07	-509	+030	+002	+580	+1026	+236	+575
08	-980	-375	-690	+068	+529	+472	+620
09	-1040	-1135	-1085	-1185	-1950	-1662	-456
10	-620	-175	-450	+050	+150	-685	-152
11	-640	+050	+270	+850	+1129	+435	+287
12	-080	+472	-130	+370	+020	-1002	-462
13	+240	+765	-480	+550	+459	-500	-465
14	-169	+729	+240	+519	+992	+431	+709
15	+830	+450	+175	+315	+402	+009	+508

SAT. ANTENNA

18. 10. 86

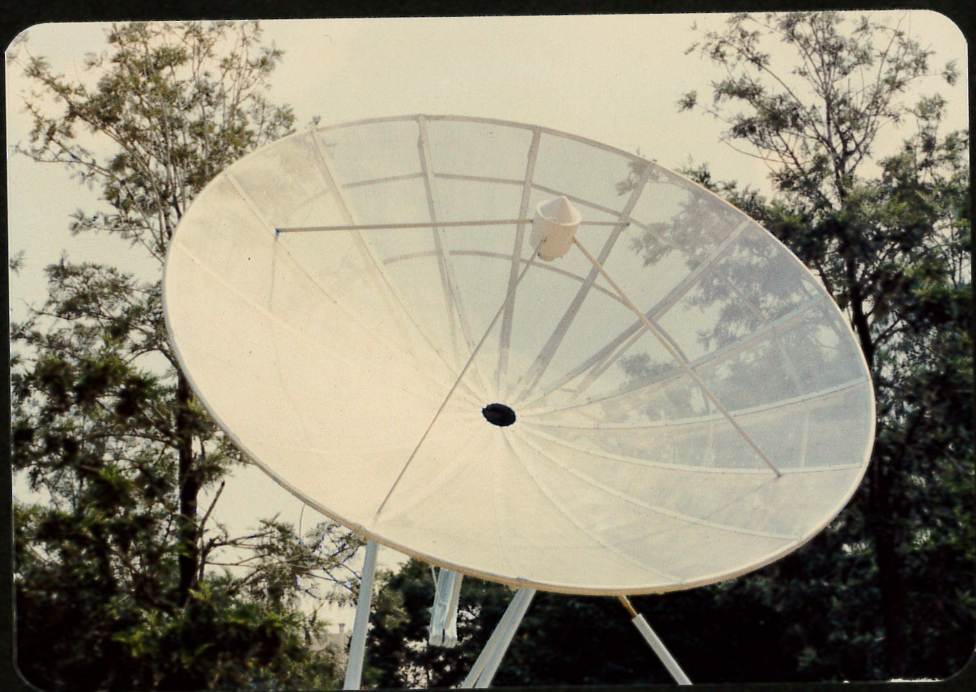


digital display unit used were made by TESA .)

The LVDT was first attached on to the first marking (made earlier on the template) at a convenient height so that the tip of the LVDT just touched the surface of the frame. The corresponding reading on the display unit was noted. Likewise, the LVDT was placed at these different markings made earlier at intervals of 100 mm and the corresponding readings were noted. Using the reference frame, the position of the other fifteen frames were fixed using the LVDT. The RMS value of dish, the vertex of dish and focal point were calculated using these readings in a computer and a map showing the accuracy of the dish in terms of microns was obtained. This map has been included. The accuracy achieved was 940 microns which is sufficient to receive signals upto 12 GHz. Immediately thereafter, the central shaft and template were removed as they were no longer necessary.

We had mentioned earlier that a circumferential support had been pro- vided by riveting together three pipes. One more inner circle of pipes were provided (smaller diameter) and attached to the top surface of the dish concentric to the previous circle.

To provide a reflecting surface on the dish a perforated aluminium sheet was cut and fixed on to the top surface of the dish. This was done by first making a cardboard template of the appropriate dimensions, and then



using this template, the aluminium sheet was cut into eight identical pieces. The sheet was then ironed out to remove kinks and dimples which might have been present. The eight pieces were then screwed on to the top of the dish using sixteen aluminium strips and self-tapping screws. The dish was then ready for the final stage of assembly.

The final stage involved the mounting of the dish, hub and hexagonal frame on the mount. This combination was placed on the channel situated at the top of the mount and the shaft running through the hexagonal frame was supported at both its end by tkwo SKF plummer blocks. A few specifications of the bearing follow:

SHAFT DIAMETER - 30 mm

HOUSING DESIGNATION - SNA 508-607

MAXIMUM PERMISSIBLE SPEED - 9500 RPM

WEIGHT - 2.65 kgs.

BASIC CAPACITY - STATIC - 560 kgs.

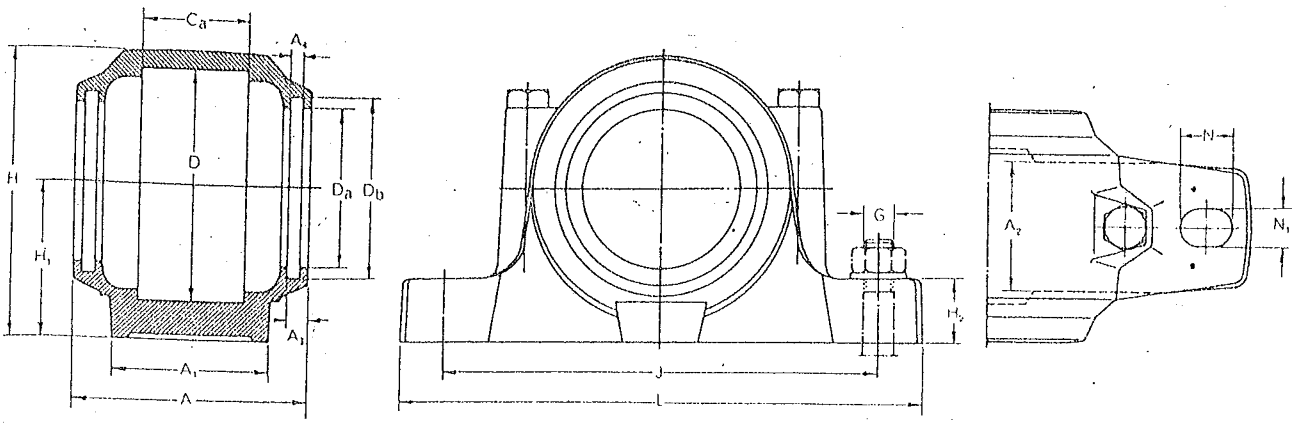
BASIC CAPACITY - DYNAMIC - 1200 kgs.

Specific bearing details have been included.

The plummer block through which the main shaft passes was fixed on the channel by means of a plate of length 237 mm and width 93 mm. This plate was bolted on to the channel at both ends by four bolts to each plate.

SKF

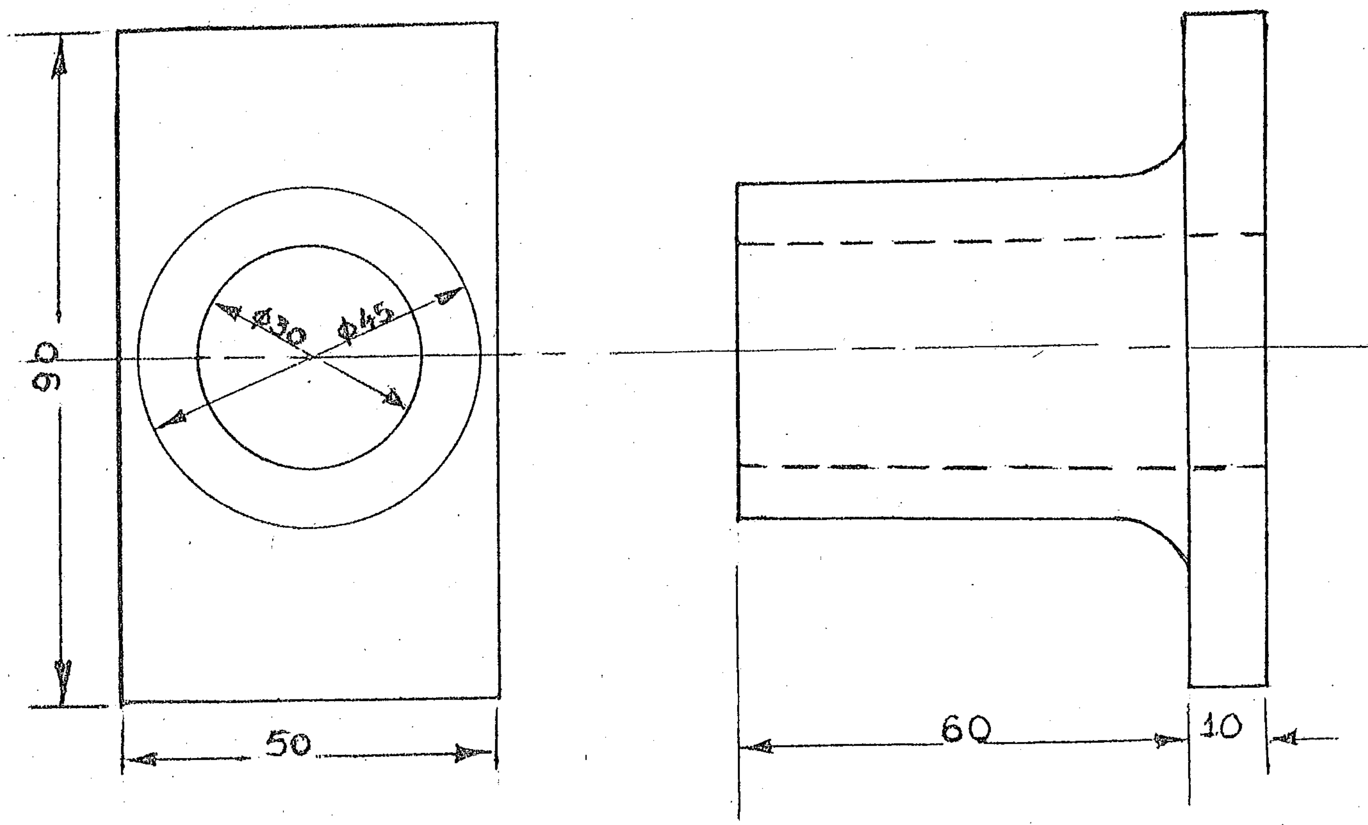
Plummer blocks



Shaft diam. d_1 mm	Housing (plummer block without seals) Designation	Dimensions mm A	A_1	A_2	A_3	A_4	C_a	D	D_a	D_b	H	H_1	H_2	J	L	N	N_1	G	Weight kg.
20	SNA 505	67	46	42	7,5	5	25	52	31	39,5	71	40	19	130	165	20	13	10	1,35
	SNA 506—605	77	52	45	7,5	5	32	62	36,5	44,5	87	50	22	150	185	22	13	10	1,90
25	SNA 506—605	77	52	45	7,5	5	32	62	36,5	44,5	87	50	22	150	185	22	13	10	1,90
	SNA 507—606	82	52	45	7,5	5	34	72	46,5	54,5	92	50	22	150	185	20	13	10	2,00
30	SNA 507—606	82	52	45	7,5	5	34	72	46,5	54,5	92	50	22	150	185	20	13	10	2,00 ✓
	SNA 508—607	85	60	50	7,5	5	39	80	51,5	59,5	106	60	25	170	205	20	15	12	2,65 ✓
35	SNA 508—607	85	60	50	7,5	5	39	80	51,5	59,5	106	60	25	170	205	20	15	12	2,65
	SNA 510—608	90	60	50	8,5	5	41	90	62	70,5	112	60	25	170	205	20	15	12	2,90
40	SNA 509	85	60	50	8,5	5	30	85	56,5	64,5	109	60	25	170	205	20	15	12	2,70
	SNA 511—609	95	70	58	8,5	5	44	100	67	75,5	127	70	28	210	255	23	18	16	4,35
45	SNA 510—608	90	60	50	8,5	5	41	90	62	70,5	112	60	25	170	205	20	15	12	2,90
	SNA 512—610	105	70	60	8,5	5	48	110	72	80,5	133	70	30	210	255	23	18	16	4,80

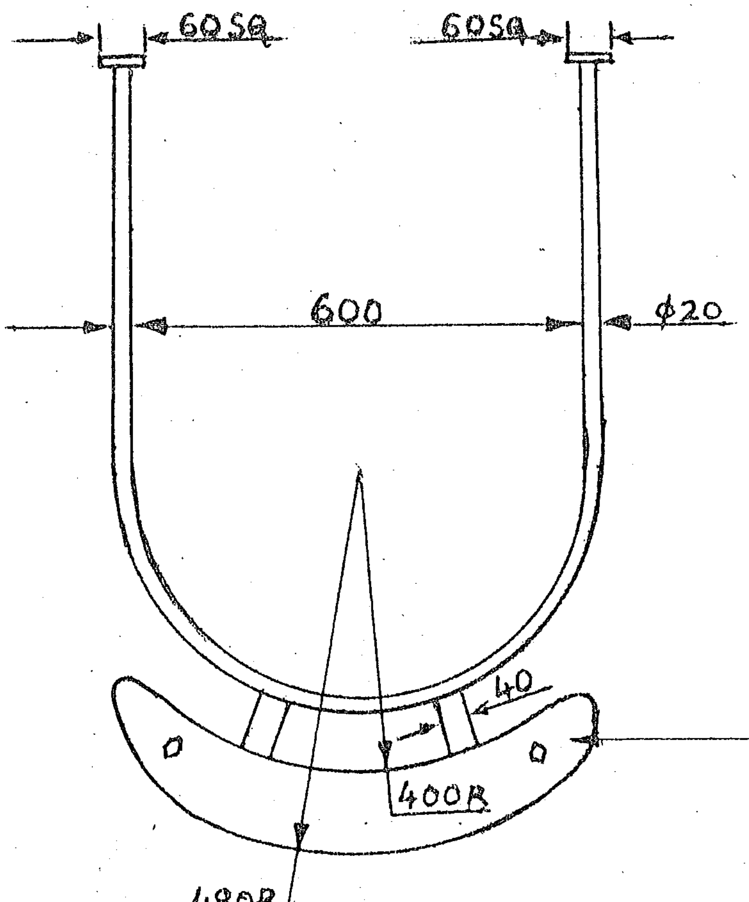
	d	D	B	Basic capacity, kg: static C_0	Basic capacity, kg: Dynamic	Max. rpm permissible
2206 →	30	62	20	560	1200	9500

Self-aligning



COLLAR
For Main Shaft

SCALE 1:4



'U' SUPPORT
SCALE 1:10

COUNTERWEIGHT
= 40 KILOS

To ensure a proper balancing of the dish when it moves to different elevation angles, a counter weight of 40 kgs. was attached to it by a U-shaped frame. A worm gear was then attached to the shaft to assist in the precise movement and locking of the dish.

SCOPE FOR FUTURE WORK

Presently, the Satellite dish has a worm gear-reduction, hand-driven unit for positioning the dish to look at different satellites and also lock the dish in position.

It is suggested that the following additional features can be incorporated in the dish drive:

1. Motorization of the dirve instead of the present hand-driven unit.

2. Remote positioning of the antenna to various satellite positions using a stepper motor drive, which could be preprogrammed using a micro-processor.