MODIFICATIONS IN THE STRUCTURE OF THE DISH OF THE MOREHEAD RADIO TELESCOPE TO FACILITATE GREATER RESOLUTION OF RADIO SIGNALS

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ABSTRACT

Radio telescopes are instruments which radio astronomers use to study the universe. These are valuable tools in that they allow astronomers to "see" certain parts of the universe not observable by the human eye. It is necessary for any radio telescope to be designed properly so that radio signals can be collected and analyzed. The purpose of this research is to make necessary modifications to the Morehead Radio Telescope (MRT) so that it will become a useful scientific instrument. At the present time, the MRT requires several modifications. The area of concentration is to alleviate the inability of the reflector to converge reflected radio signals to a single focus point on the antenna horn. The proposed solution to this problem is to modify the shape of the reflector in order to facilitate more effective convergence of the reflected radio signals. This will involve modifications in the shape of the dish of the radio telescope.

I. Introduction

The detection of radiation from remote objects is essential to obtain knowledge of these objects. The most familiar form of this detection is seeing objects with the human eye. However, only a small portion of radiation can be detected by the human eye. If remote objects do not produce radiation in the visible spectrum, instruments must be devised to detect these other types of radiation. The radio telescope is one of these instruments.

The radio telescope can be used to detect objects that are visible or invisible to observers. With the radio telescope, observers will be able to "see" such things as quasars, galaxies, cosmic jets, black holes, nebulae, supernovas, pulsars, and planets. Observers can also conduct studies such as the search for the galactic center, search for glycine, or even the search for extraterrestrial intelligence.

In order for radio waves to be detected, they must first be gathered and brought to a focus onto a detector. The dish of a radio telescope is responsible for this task. Critical to these functions is the shape of the dish. The MRT (Morehead Radio Telescope) which is presently under construction, does not sufficiently gather and focus radio signals to a degree necessary for the instrument to provide meaningful data. It is assumed that the MRT dish presently does not possess the shape needed to properly gather and focus radio signals. The purpose of this research project is to find the needed shape and measurements for the dish and report this information to engineers involved in the construction of the MRT.

II. Principle of the Reflector

In order for a radio telescope to effectively focus reflected radio waves onto a detector, the receiving dish must be in the shape of a parabola. When the detector is placed at the focal point of the parabola, the reflected radio signals are collected for analysis. As each part of the wave front reaches the reflecting surface, its polarity is reversed, and it is sent outward at an angle of reflection that is equal to the angle of incidence. Refer to figure 1. All parts of the wave front will arrive at line AB at the same time, since each length from the focal point to the reflector is the same. Thus, with this parabolic reflector, all parts of the wave front are reflected in a direction parallel to the axis and are in phase at all points in a plane across line AB (Antenna Group 39-41).

II. The Problem

The fact that the dish does not presently possess the required shape was demonstrated with Dr. Whidden's computer program "MRT1." The output of this program showed the present shape of the dish through measured data points taken directly from the design. The program simulated radio signals projected onto the dish and reflected toward the focus point. However, this program showed that the dish was so irregularly shaped that some radio signals went to waste by bouncing off in random directions.

III. Corrections to the Problem

In order to correct this irregular shape, an equation for a parabola must be derived. The equation is then used to create the "corrected" diagram for the irregular dish shape. The equation for this parabola is for a special case. The focus is on the x-axis and the vertex is at the origin. See figure 2. The focus is the point F(p,0) and the directrix is the verticle line x = -p. The equation of the parabola with these conditions is:

$$y^2 = 4px.$$

In order to write the final equation for the parabola for the MRT dish shape, the focus point must be found. Refer to Figure 2. The focus point is occupied by the antenna. The dimensions are given from the antenna back to the reflector. The sum of these dimensions will give the location of the focus point. The reflector will be considered to be at point (0,0). The sum of the dimensions from the reflector to the antenna is:

(33 9/16 + 10 1/4 + 111 15/32) inches = 155 9/32 inches.

This places the antenna at the point (155 9/32, 0). Thus, the equation for the parabola is:

$$y^2 = 4px \quad (1)$$

$$y^2 = 4(155\ 9/32)x$$

$$y^2 = 621\ 1/8x$$

$$y^2 = 621.125x \quad (2)$$

Equation 1 was used in a computer program called "Par" written by Dan Puckett. This program allows the user to calibrate the computer output of the parabola to the scale of the MRT. The program asks the user to enter the distance from the reflector to the antenna. The output is then a drawing of the parabola showing where the focus point is relative to the vertex of the parabola. The output of this program can be printed out and an engineering over-lay can be made to place over the engineering drafts of the present MRT dish shape. This will show where the deviations are in the MRT dish shape in two dimensions.

When trying to convert equation 2 to a three dimensional equation, a paraboloid conic shape must be chosen. Of the several types, the best selection would be the circular paraboloid because of its ability to reflect rays at angles of incidence equal to the angles of reflection. The equation for a circular paraboloid is:

$$z = x^2/a^2 + y^2/a^2.$$

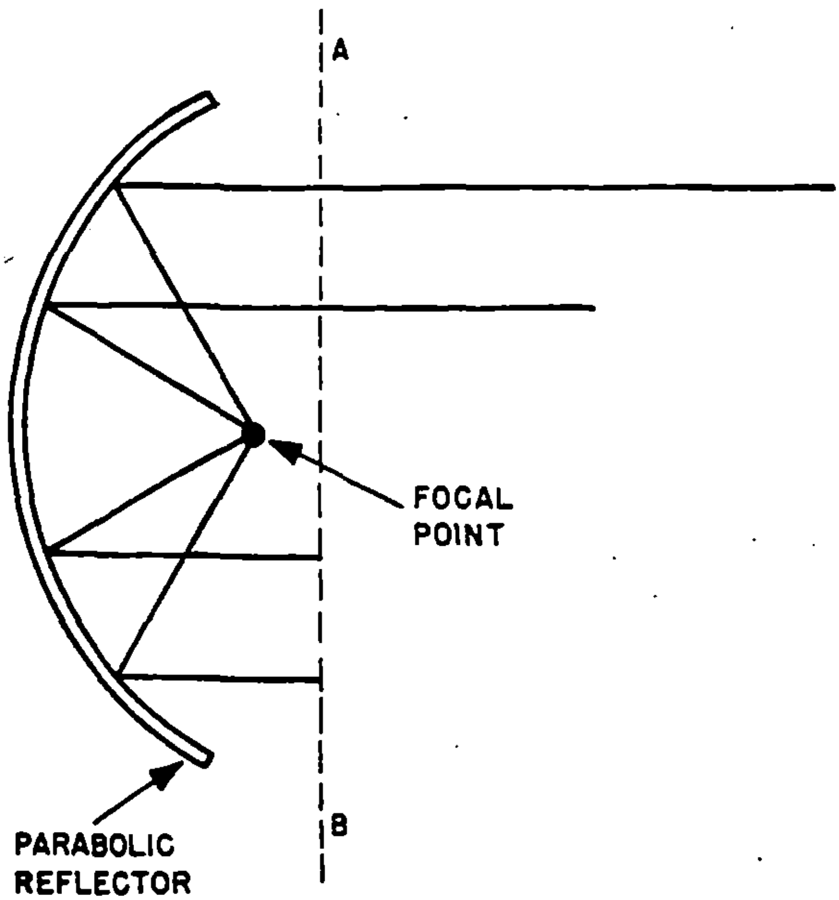
Since the equation for the parabola in two dimension is $y^2 = 621.125x$, in three dimensions the equation for the circular paraboloid is:

$$z = x^2/621.125 + y^2/621.125.$$

Figure 4 shows what the circular paraboloid looks like using the computer program "Derive." It must be lastly noted that the circular paraboloid is not the shape of the MRT dish itself. It will be some cross-section taken from the side of the paraboloid. This section can be located by assembling a model of this three dimensional shape, comparing it to an actual model of the MRT of the same scale, and cutting away the excess of the paraboloid.

IV. Conclusions

It is essential that complex scientific instruments be designed with a certain amount of precision. The difficulties associated with the MRT demonstrate this. However, since many devices are designed based upon mathematical concepts, it can be fairly easy to suggest ways to improve a design. Computer programs can prove invaluable with the use of equations and in the production of diagrams, saving engineers time and increasing the effectiveness of corrective measures. Scale models are also very useful, as they are actual three dimensional representations and not three dimensional objects drawn in two dimensions.



TM5047-28

Figure 1

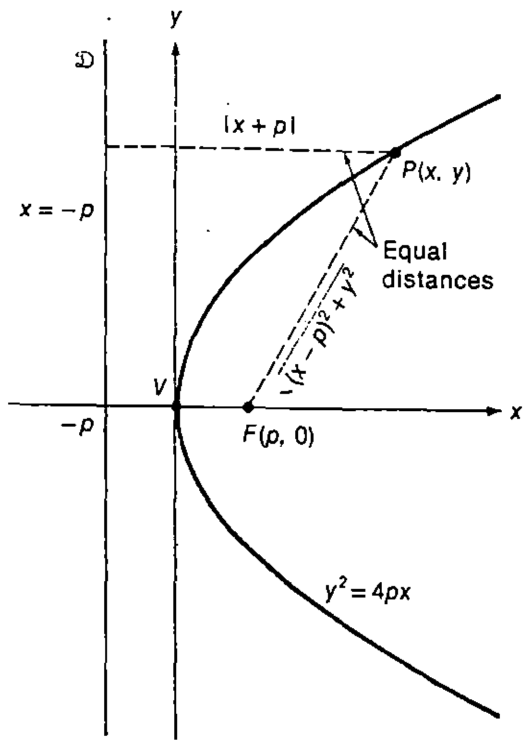


Figure 2

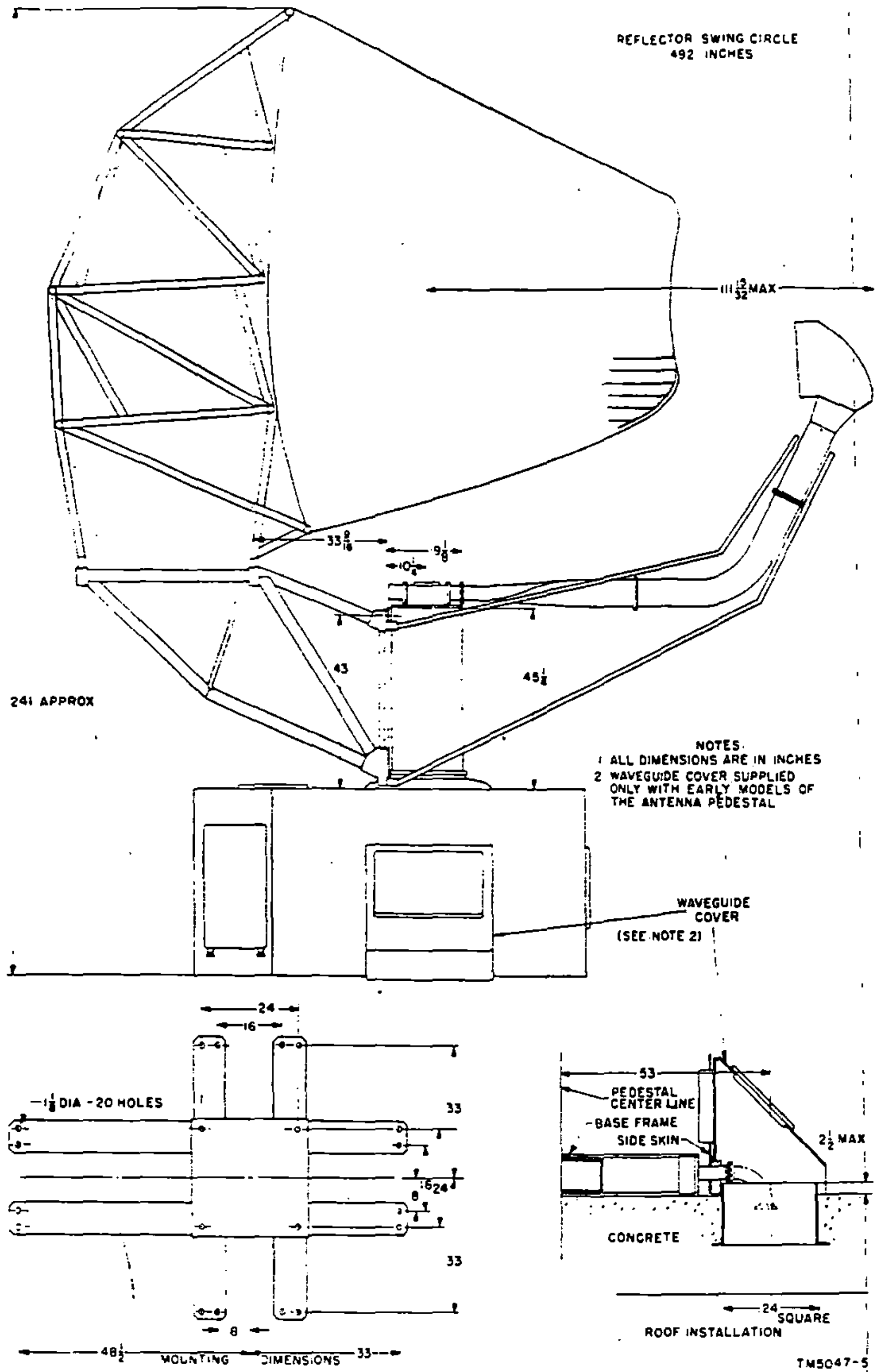

REFLECTOR SWING CIRCLE
492 INCHES
111 13/32 MAX
33 9/16
9 1/8
10 1/4
43
45 1/8
241 APPROX
NOTES
1 ALL DIMENSIONS ARE IN INCHES
2 WAVEGUIDE COVER SUPPLIED ONLY WITH EARLY MODELS OF THE ANTENNA PEDESTAL
WAVEGUIDE COVER
(SEE NOTE 2)
24
16
1 1/8 DIA - 20 HOLES
33
6
24
8
33
8
48 1/2
MOUNTING DIMENSIONS
33
53
PEDESTAL CENTER LINE
BASE FRAME
SIDE SKIN
2 1/2 MAX
CONCRETE
24 SQUARE
ROOF INSTALLATION
TM5047-5

Figure 3

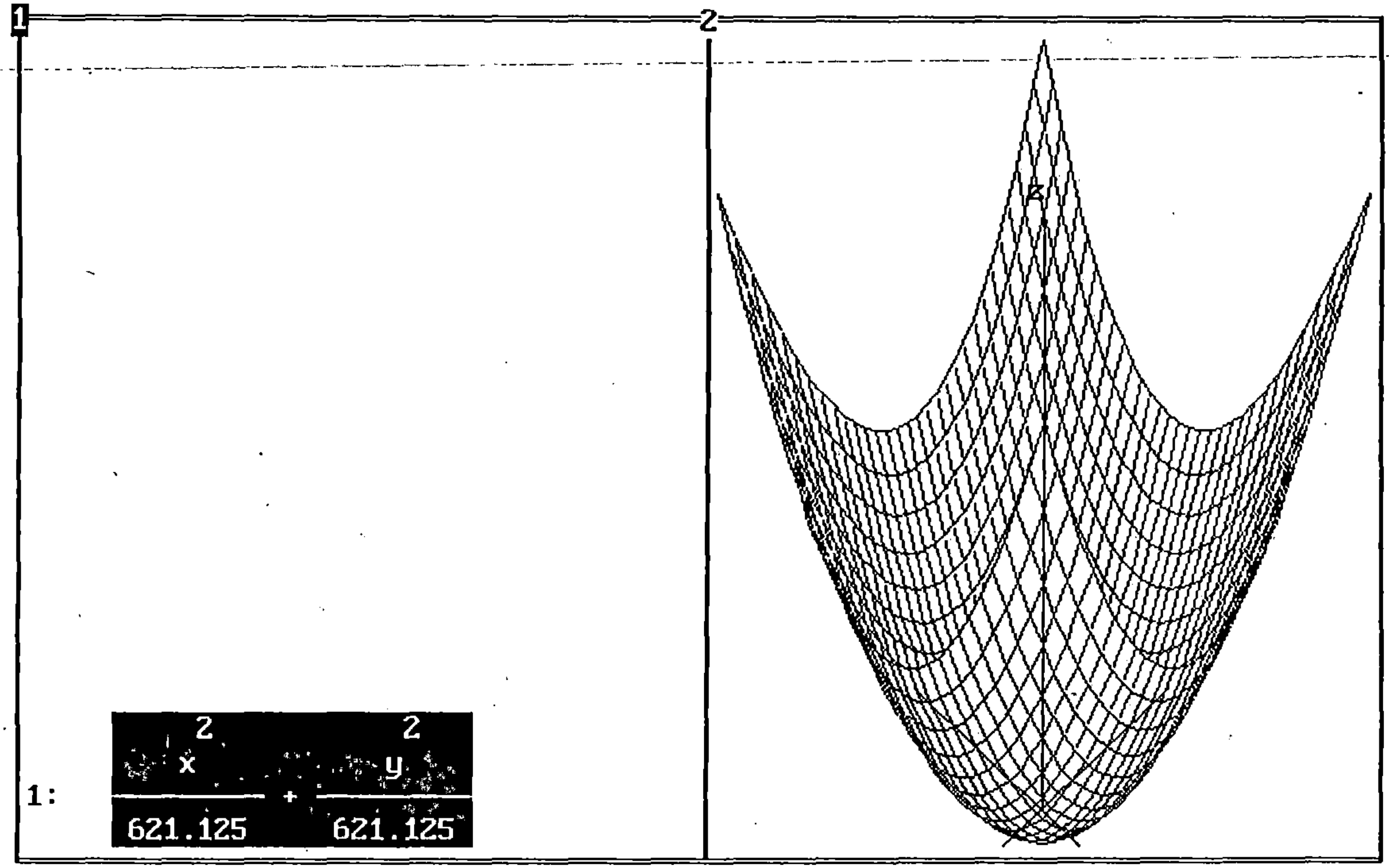


Figure 4

BIBLIOGRAPHY

Antenna Group OA-1124/FPS, TM 11-5047 Department of the Army Technical Manual, Department of the Army, 3 April 1957.

Puckett, Dan, "Par," unpublished computer program, 1994.

"Reflector, Center Section Assy.," Blueprint drawing #SM-D-293877 (sheet 2), Department of the Army Signal Corps Engineering Laboratories, 21 Feb. 1957.

"Reflector, Center Section Assy.," Blueprint drawing #SM-D-293877 (sheet 3), Department of the Army Signal Corps Engineering Laboratories, 19 Feb. 1957.

"Reflector, Section #2 Assy., " Blueprint drawing #SM-D-293878 (sheet 2), Department of the Army Signal Corps Engineering Laboratories, 21 Feb. 1957.

"Reflector, Section #2 Assy., " Blueprint drawing #SM-D-293878 (sheet 3), Department of the Army Signal Corps Engineering Laboratories, 22 Feb. 1957.

"Reflector, Section #3 Assy., " Blueprint drawing #SM-D-293879 (sheet 2), Department of the Army Signal Corps Engineering Laboratories, 26 Feb. 1957.

"Reflector, Section #3 Assy., " Blueprint drawing #SM-D-293879 (sheet 3), Department of the Army Signal Corps Engineering Laboratories, 26 Feb. 1957.

"Reflector, Section #4 Assy., " Blueprint drawing #SM-D-293880, Department of the Army Signal Corps Engineering Laboratories, 25 Feb. 1957.

Shockley, James E., Calculus and Analytical Geometry, Saunders College Publishing, Chicago, 1982, pp. 395-403, 793-802.

Spangler, Ron, "AutoCad," Versions 11 and 12, registered program, 1993.

Whidden, Jack, "MRT1," unpublished computer program, 1994.