Geodesic Parabola Antenna

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Abstract

Geodesic Parabola Antenna (**Photo-1, -2**) is a kind of stressed-dish which is approximated by triangular planes. Its novel structural features are light weight, stiffness and ease of construction. This article reports background of the design and construction details.

Introduction

As the readers may be aware, the name of "Geodesic" is derived from "Geodesic Dome" structure invented by Richard Buckminster Fuller [1]. When searching for a better way to construct a stressed parabola, the author was not originally inspired by the Geodesic Dome structure, but through experiment reached the conclusion that a Geodesic dome would satisfy the requirements of a stronger, lighter structure. To "Do more with less" as proposed by Fuller.

The main advantage of this antenna is its "easy-to-construct" nature, featuring the following points.

a. No template or pre-bending work is required in construction of the frame.
b. The parabolic curvature results directly from the construction method.
c. Mesh on convex side, not on concave side of reflector.
d. Homogeneous triangle segmentation provides a robust structure and better surface accuracy.

The first three of features are derived from a collapsible (umbrella) antenna (**Photo-3, -4**) which was constructed by the author prior to the Geodesic Parabola antenna. Since both of the antennas are based on the so called "stressed dish" design [2], the features (a) and (b) carry through to this design. The feature (d) improves upon a disadvantage of conventional dish antennas whose structure consists of radial and axial frames. In the conventional design a unit segment made by radial and axial frames is trapezoidal in shape. Therefore the segment would be weak against side forces. In such a conventional structure, additional members are mandatory to reinforce the trapezoid and doing this results in a triangular segmentation. From a surface accuracy point of view, increasing the number of radial frames is a common method of improving the surface accuracy in the conventional stressed dish structure. However, this method has the negative side effect of increasing the weight and introducing unequal segmentation. This side effect results in an inefficient structure. Again, with ingenuity, we can "do more with less".

The features mentioned above are inherent in the design and are complementary to each other, each contributing to the overall superiority of the design.

Design

Design parameters of the antenna are:

f/D = 0.35
Diameter = 917 mm (7.3 wavelength)
Focal length = 320 mm
Depth of dish = 164 mm

Since the length of off-the-shelf aluminum flat bar is 1 meter, the diameter is restricted by this length. (see **Figure-1**) The size of dish would be suitable for the S-band downlink of a Phase-3 type satellite earth station. Considering the accuracy of the dish surface produced in the Geodesic design, S-band would be the highest frequency usable. The topic of surface accuracy is fully discussed in a later section.

In conventional design of a stressed dish, a large f/D number such as 0.5, (or shallow dish) is popular to make it easier for the constructor to more closely approximate a parabolic curve. This design employs a smaller f/D number resulting in a more stable, less top-heavy dish which can at the same time employ a patch feed for good illumination and minimum over-spill.

Structural design does not require mathematical analysis. It is easily done by the method of technical drawing and some simple calculation by Excel spread sheet. The Excel sheet is not ready for public release due to lack of a friendly interface for users.

Construction

Table-1 lists the materials. The readers may feel that 2 mm thickness of aluminum flat bar is too thin to maintain the structure. However, they will come to recognize the inherent stiffness of the structure as their own construction proceeds. It should be noted that the size of the screws, and therefore, the screw holes should be kept as small as possible in order to maintain resilience of the aluminum flat bar. The resilience and strength of the material must be maintained and is essential to the success of the stressed dish. With this in mind, thin wire is employed to sew the mesh, thereby eliminating the need for further holes in the frame structure.

Figure-1 shows dimensions of three ribs. As requirement on dimensional accuracy is moderate, hand-tools would be enough for mechanical work. The quantity of each rib is three pieces of Rib A, six pieces of Rib B and twelve pieces of Rib C.

Segmentation of the mesh is different from conventional fashion. Some trials resulted in using the figuration shown in **Photo-5** to make the dish surface smooth when employing the "mesh-on-convex" design. **Photo-5** also shows that the segmentation consists of three pairs of trapezoid and crescentic shapes.

Here are some tips for assembling.

a. Connection of fringe ribs (Rib C) may appear a little puzzling. **Photo-6** and **Photo-7** clearly explain the order of connections.

b. As mentioned above, the structure is very stiff. If you have difficulty in aligning the aluminum flat bars during the final phase of assembling, it is recommended you use string to bow the bars temporarily.(**Photo-8**)
c. Numbers on **Photo-9** suggests the order of sewing the mesh.
d. Two pie-dishes are glued by epoxy in order to reinforce the structure.
e. Saddle washers should be inserted between ribs and center-hub in order to fill up gaps as shown in **Photo-10**. The curvature of ribs may be distorted without these washers when the center-hub is attached.
f. Supporting brackets are made from the same material as the ribs as shown in **Photo-11** and **Photo-12**.

Results

The accuracy of any dish surface is of great importance and will be of prime interest to readers. This has been thoroughly researched. **Photo-13** shows deviation from the ideal shape of a parabolic curve. A maximum deviation of approximately10 mm or 1/12 wavelength is measured as the peak deviation from an ideal surface. The surface displays a periodicity of approximately 200 mm, or 1.6 wavelength. These two numbers allow an accurate assessment of the surface accuracy and therefore the efficiency of the dish. According to chart (Fig 8.102) of the reference [2], it is expected that these measured values would result in approximately 2 dB degradation of antenna gain.

Figure-2 shows measured radiation pattern of patch feed. Efficiency of the parabolic antenna is calculated using this measured data by W1GHZ's software FEEDPATT.EXE [3]. The calculation result shows 65 % of efficiency, or 2 dB degradation of antenna gain as shown in **Figure-3**. It is noted that f/D=0.35 is not optimized for the patch feed.
The maximum gain of an ideally shaped parabolic antenna of this size is calculated as 27 dB at 2.4 GHz. Considering the degradation mentioned above, 23 dB or less can be expected from this dish. It should be noted that any gain figures for parabolic dishes can be a bit "rubbery" and should taken as a guide only.

The Geodesic dish constructed from this article can be expected to have a total mass of approximately 1.3 kg, including the patch feed and mounting brackets. Individual construction methods may of course result in a few grams either way. The author has received a report from a user that the Geodesic Parabola Antenna withstood heavy storms thanks to its light-weight, stiffness and flexibility of structure. Another user reports that the antenna is very suitable for portable operation for the same reasons.

Acknowledgment

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References

[1] The Buckminster Fuller Institute, http://www.bfi.org
[2] Evans, D.S. and G.R. Jessop, VHF-UHF MANUAL (3rd. Edition), RSGB 1976, pp. 8.56-8.57
[3] Paul Wade W1GHZ, http://www.w1ghz.cx/antbook/contents.htm