STRESS DISHES REVISITED

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Abstract - **Stress parabolic reflectors offer a lightweight, high-gain antenna ideally suited for EME on the UHF and lower microwave bands. They require minimum skill for construction and can easily produce gains in excess of 25 dB, depending on size and frequency.**

Introduction

Interest in stress dishes for EME has decreased in recent years because of the availability of relatively inexpensive TVRO dishes [1]. There are still many applications were the stress dish concept could be put to good use. Stress dishes can be constructed to have less wind resistance and significantly lighter than a similar sized TVRO dishes. Stress dishes can also be produce in form that is highly portable making them ideal for temporary and dxpedition operation [2,3,4].

Parabolic reflectors have been extensively used for EME on 70 cm and above. This popularity is due no-doubt to two outstanding features. First, the performance of the parabolic reflector is (within certain limits) frequency independent. The reflector once constructed can be used on a variety of frequency bands depending on the feed antenna used. This feature is highly desirable as the antenna can be used on more than one band during portable operation.

Secondly, if the reflector's surface tolerance is maintained, the antenna's gain efficiency is independent of size. This is not the case for array type antennas, where losses due to the phasing harness increase with array size.

Figure 1 Twenty foot stress parabolic reflector used on 432 EME for many ears at K2UYH and later W3CCX

The disadvantage of conventional parabolic reflectors, particularly most available TVRO designs, is their weight and wind loading. The stress parabolic reflector totally overcomes the first of these disadvantages and partially the second. Further, it can be produced for a very low cost and requires a minimum of time and skill for its construction. For moonbounce operation it also allows either circular polarization or polarization rotation to be easily implemented.

Stress Principle

When a beam is loaded at its end, it deforms in an approximate parabolic curve. This is the principle from mechanics that the stress parabolic reflector is based upon. The heavy structure that supports the surface of most parabolic reflectors is replaced by a set of spokes, which are bent into an approximate parabolic shape with guy lines. Each spoke is basically a cantilever beam. The equations of bending predict a parabolic curve for small deflections. The amount of deflection for most parabolic reflectors is not small; neither is the loading perpendicular to the beam (adding the effects of column action to the total deformation). For these reasons, mathematical prediction of the resultant curve is rather complex. The expected curve can be evaluated empirically by constructing a number of models.

The deflection of a typical spoke is illustrated in Figure 2.

Data from numerous models and actual working reflectors reveal that the relative shape is insensitive to material and cross-sectional area. The greatest error occurs along the third quarter of the spoke's length and is always is in the direction of too great a deflection. The curve is also insensitive to the angle (α) the guy line

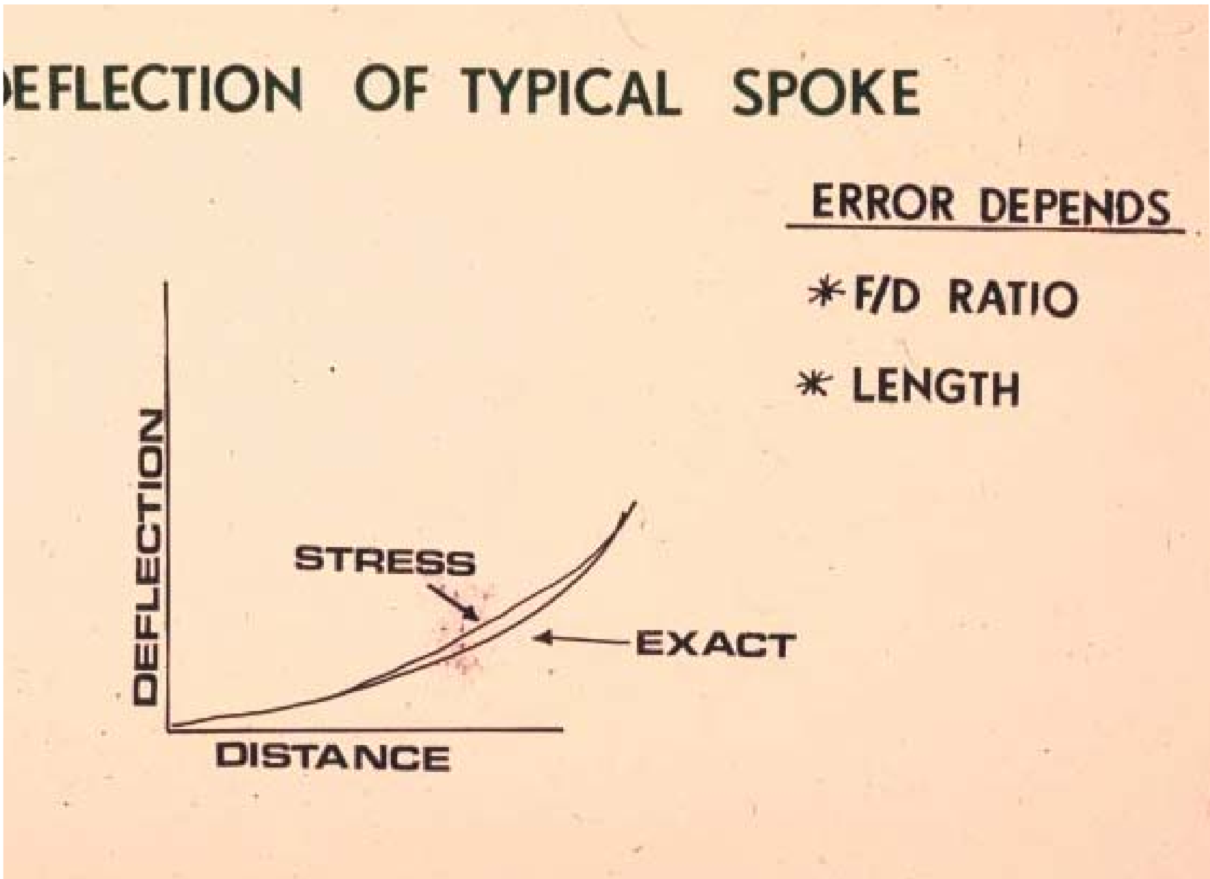

Figure 2 Deflection of a typical reflector spoke – f/d = 0.5

makes with the reflector's normal. A lightly better curve shape is provided by larger angles. Shape is also related to the focal point to diameter ratio (f/d) and the diameter of the dish. Smaller f/d ratios yield greater bending and hence greater error. Likewise, as dish diameter is increased, the absolute error increases in proportion to size. See Figures 3 and 4.

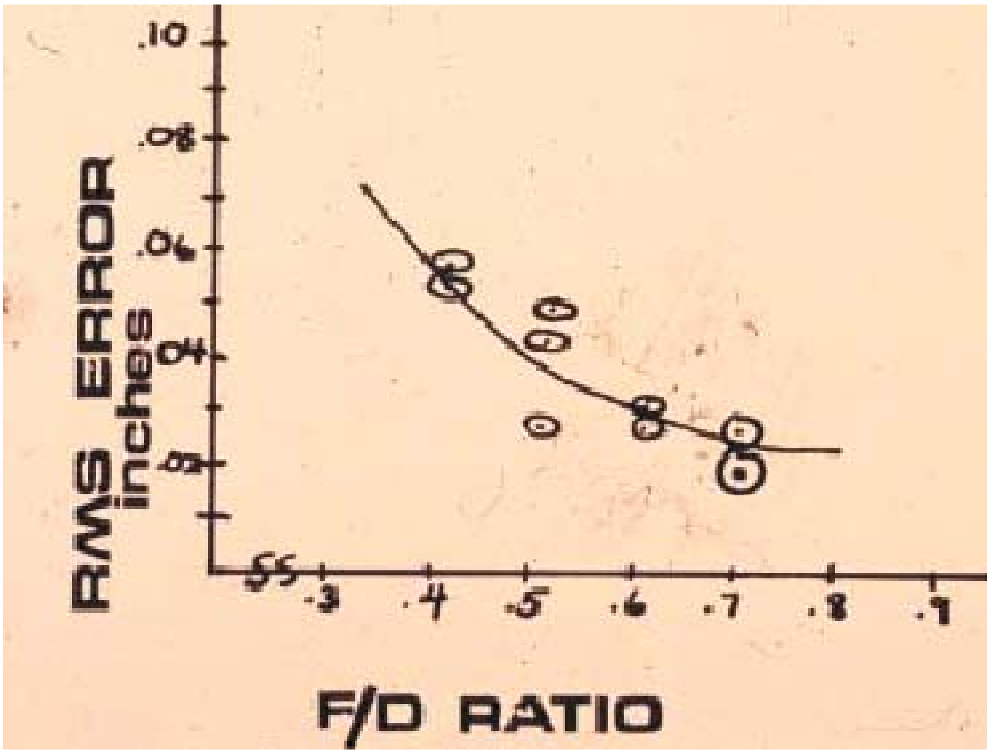

Figure 3 Variation of RMS error with reflector f/d ratio

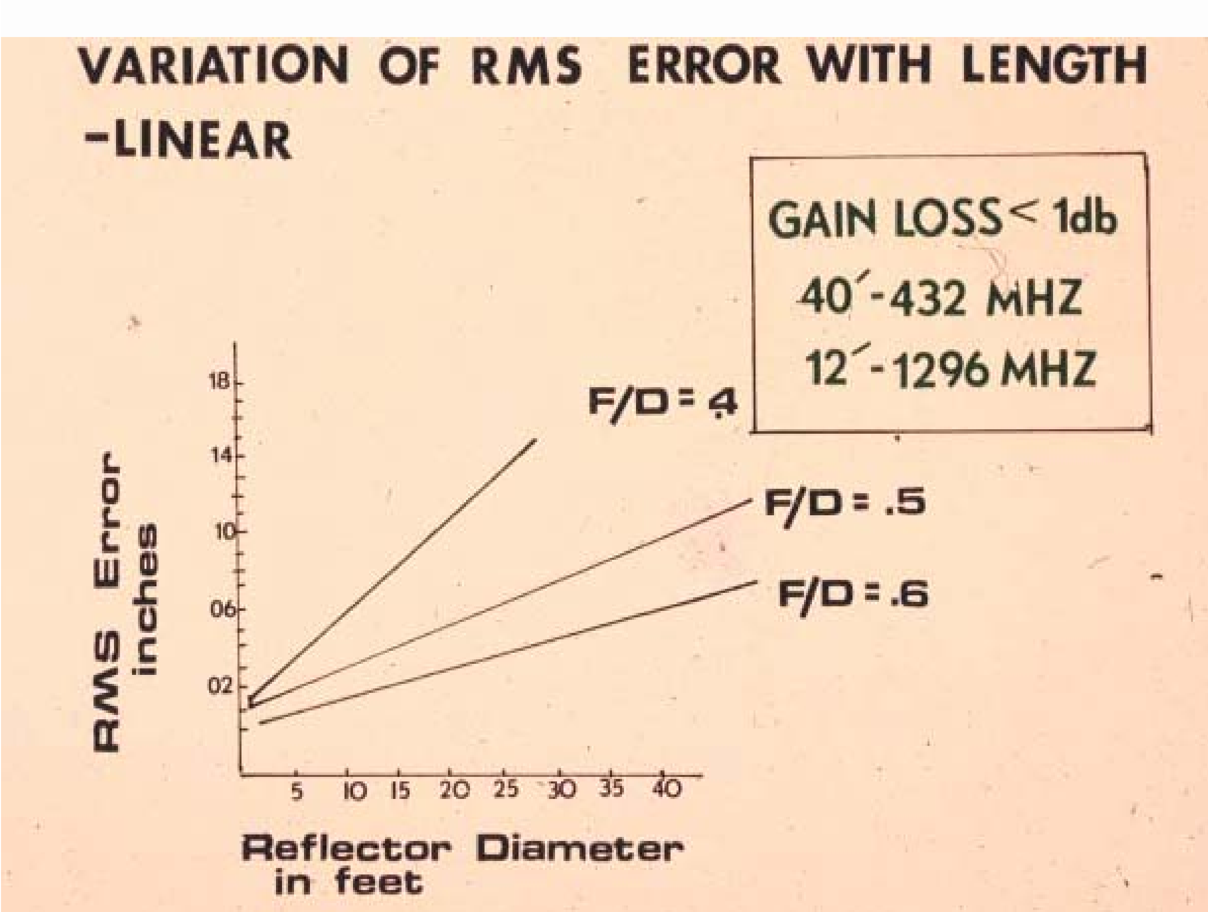

Figure 4 Effect of f/d ratio and reflector diameter on surface accuracy

The maximum error of the spoke of Figure 2 (length = 6 feet, f/d = 0.5) is .52 inches and its approximate RMS error is .395 inches. A reflector constructed from such a spoke would have a diameter of 12 feet and a loss in gain due to surface error of less than 0.1 dB, 1 dB and 2.5 dB on 432, 1296 and 2320 MHz respectively [5,6]. This performance is obtained without any curve measurement; only the bending of the spoke ends to a depth corresponding to the desired f/d ratio.

In practice, the reflector's surface accuracy can be significantly improved by correcting the stress curve. Generally some form of correction is desirable for reflectors of greater than 12 feet in diameter at 1296 and above. Surface error correction can be achieved by either pre-stressing the spokes beyond their elastic limit in a manner that corrects for the stress curve's error – this was the approach taken for N2UO's dish shown later.

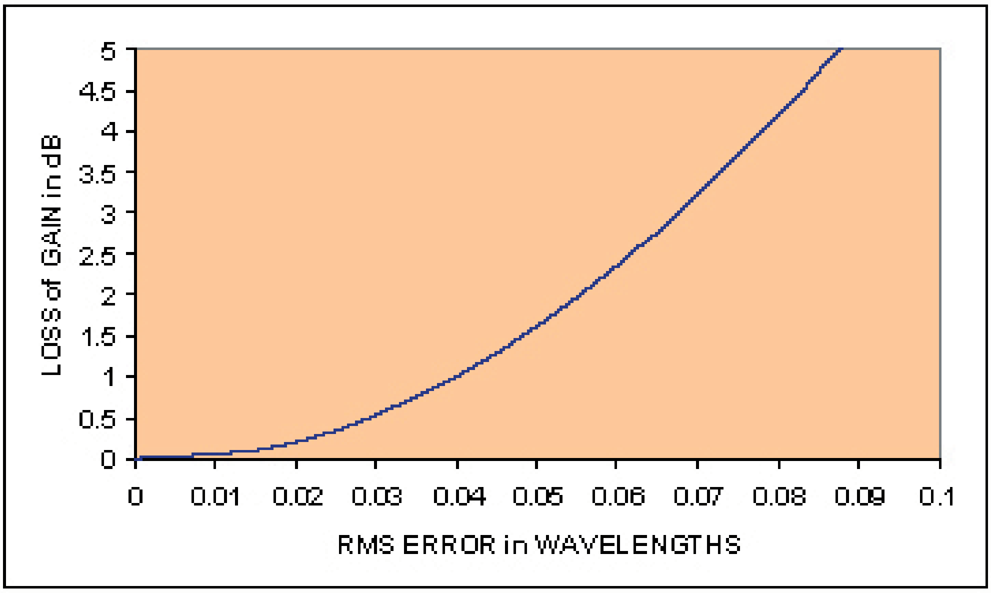

Figure 5 Gain loss due to RMS surface error

Alternately back guying or the addition of a rigid circle at the point of maximum error (approximately ¾ the length of the spoke) can be used for correction – this was the approach used in the dish of Figure 1. Variations of these approaches have been used to extend the usable frequency range of stress dishes above 13 cm. On 432 MHz, stress dishes with diameters greater than 40' have been built with success. W5LUA used a 24' stress dish for many years on 1296 and 2320 MHz.

Construction

Stress parabolic reflectors have been constructed in a variety of sizes and shapes using wood, metal and plastic materials. The reflector pictured in Figure 1, constructed by the author, is typical of these. This antenna is 20'in diameter, has an f/d ratio of 0.55 and weighs less than 140 pounds. It was primarily used for moonbounce on 70 cm, where it showed a gain of 27.5 dBi. It is composed of 18 Aluminum spokes of 10 feet in length, 5/8 inches in diameter and 1/16 inch in wall thickness. These spokes are fastened together at the center in a sandwich between two 1/8-inch thick hexagonal Aluminum plates (two feet across). The center mask is a 1.5-inch diameter Aluminum pipe, and is attached to the center plates by means of a standard pipe flange. The individual spokes are bowed to the center mast by means of 1/8 inch Nylon cord. (These lines could be made of conducting material, however, dielectric lines are preferred as they cause less interference to the field of the feed antenna.) The center mask also serves as a support for the feed antenna and can be used as a conduit for the feed transmission line.

A length of #9 galvanized wire is run around the periphery of the spokes and adjusted to the proper diameter. In addition nine 5 foot lengths of 1.25 inch thick walled Aluminum tube are bolted to the back of the center plates, behind alternate spokes. This back frame serves two purposes. Running guy lines from the ends of each spoke to the back frame protects the reflector from winds approaching from the rear and helps keep the reflector in shape. Also the back frame provides points to which guy wires can be attached for correcting the errors in the stress curve.

The surface of the reflector is covered with four-foot wide strips of one-inch hexagonal chicken wire. This material was rolled across the surface of the dish and fastened to the spokes with small pieces of wire. Chicken wire is readily available, inexpensive, and offers a minimum of wind load (less than 10 percent filled aperture). Its main disadvantage is feed-through on the higher bands. At 1296 it has a loss of about 1 dB.

The dish shown in Figures 6 and 7 was designed for operation on 23 cm and above. It is only 10 feet in diameter. Similar construction techniques were used for this antenna as the 20-foot dish. However, it was covered with Aluminum screening to minimize loss on 1296. The screening was low cost and readily available. Other materials can be found that offer lower wind resistance without any degradation in performance. Because of this dish's lightweight, it was mounted on wheels and is stowed out of sight when not in use. It is hard to understand why anyone would consider using yagis on 1296 for EME, when a small dish allowing circular polarization can be constructed so easily using the stress approach.

Figure 6 N2UO 10' stress dish with 1296 feed on wheeled azimuth-elevation mount

Figure 7 a). Back of dish – note wire for attaching mesh b) Mounting wheel details

Portable Dish

Figures 9 shows the details of a stress dish that was specifically designed for portable operation. Although 20 feet in diameter, this dish can be assembled in less than 30 minutes, and can be carried on the top of a small car. It has been used in successful moon bounce dxpeditions from ten different locations. A 4-foot diameter plywood central hub is used to keep the spokes short (8 feet). Channels are mounted on the hub to accept the spokes without bolting them in place. A rigid outer ring and correction ring is formed from short length of rod pre-mounted to the spokes. The chicken wire covering is also pre-attached to the spokes to allow rapid assembly.

Figure 8 Portable 20 foot stress dish in DE. Carried on top of car

Feed Antennas

The gain of a parabolic reflector is dependent on its feed antenna. A great variety of feeds have been used with stress dishes. The reflector shown in Figure 1 utilizes a dual dipole feed originally developed by NIST as a standard gain antenna [7]. It is an excellent feed for 70 cm operation with f/d dishes around 0.5 (0.45 to 0.6). For deeper dishes the quad element feed shown with the portable 20-foot dish or a ring dipole work well. On 1296 MHz, the VE4MA Scalar feed is a good choice for deeper dishes (<0.5 f/d) and the IMU feed for shallower f/d dishes [8,9]. Both these feeds provide circular polarization, used almost exclusively for 23 cm EME. On 432 MHz and below linear (preferably rotatable) polarization is the standard.

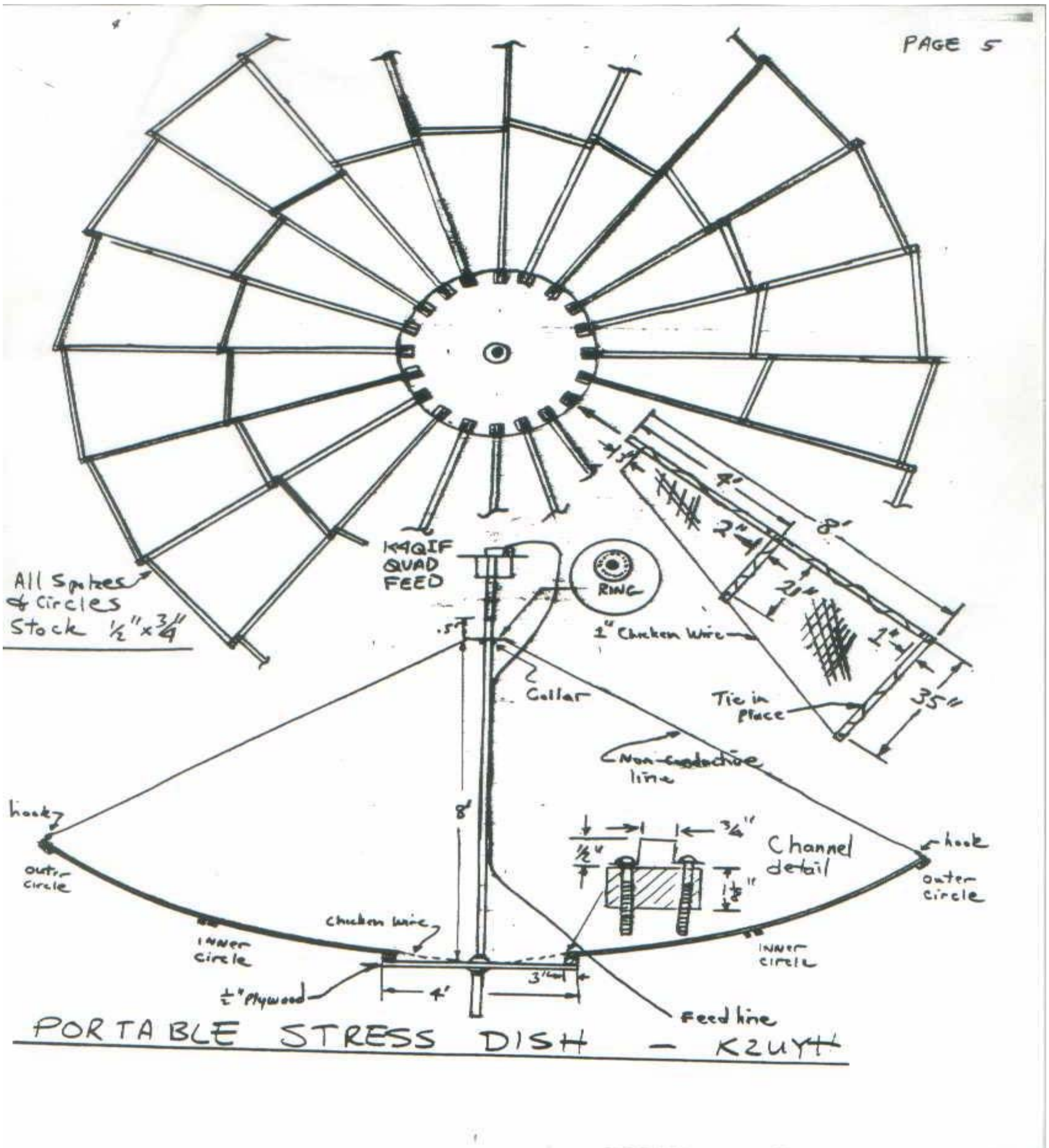

Figure 9 20' portable stress used in ten EME dxpeditions

Figure 10 Portable 20' stress dish. a) Assembly, b) In operation, and c) Center hub

Conclusion

Stress dishes, although not as rugged as rigid dishes, provide an inexpensive means for obtaining large dishes (> 8 m) for UHF EME operation. With back bracing and careful design, they can be made to survive for many years. They are especially attractive for portable and temporary operation where their lightweight and ease of assembly is of prime importance. Variations on the dish reflector as cylindrical parabolic reflectors and segments offer interesting possibilities, and should also be considered. Smaller stress dishes are a good antenna choice for EME on 23 and even 13 cm. They can be constructed with less effort than other forms of antennas, allow the use of circular polarization, and provide an opportunity to try EME at low cost.

Acknowledgement

The author wishes to acknowledge the contributions to stress parabolic reflector design of K2RIW, W2IMU, VE7BBG, N2OU (ex-LU6DW) and many other amateurs.

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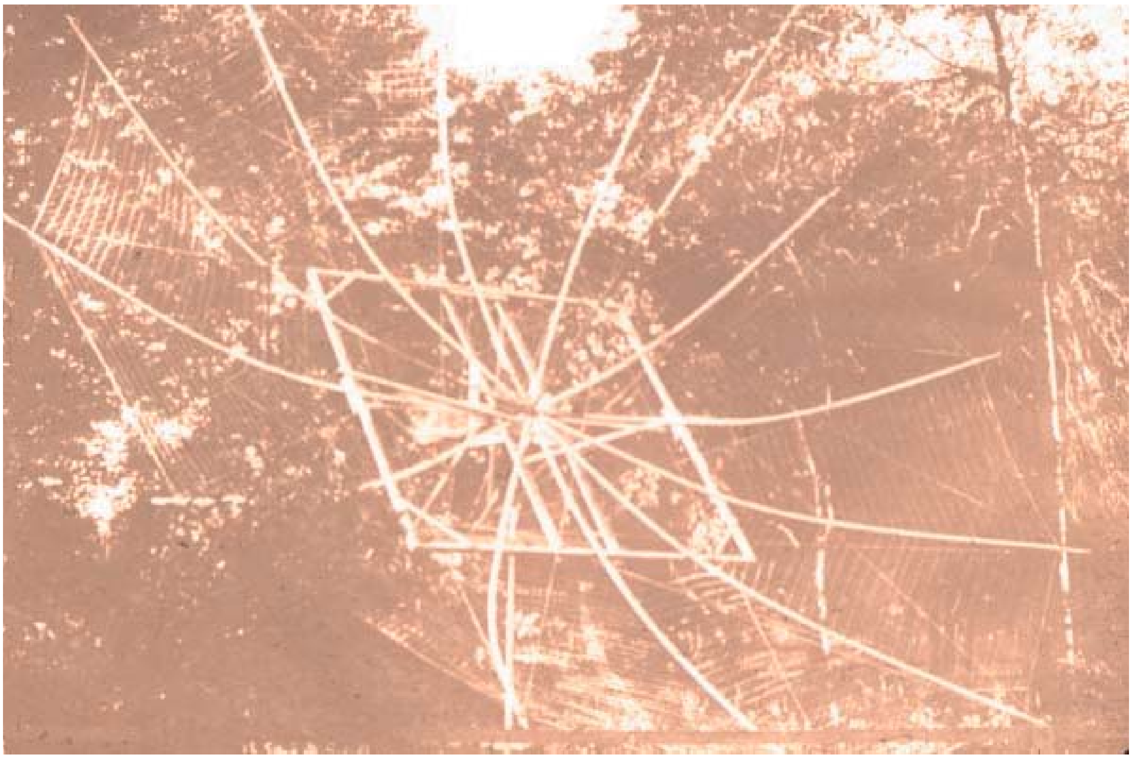

Figure 11 First stress dish (30' diameter) constructed by K2UYH in 1960