HIGH POWER MONOPULSE TRACKING FEED

For

Lincoln Laboratory High Resolution Radar

A. F. Sciambi, Jr.

K. R. Goudey

Aeronutronic Ford

Palo Alto, Ca.

ABSTRACT

This paper covers the design, development and test of a 10 GHz 10% bandwidth high efficiency feed system for the Lincoln Laboratory High Resolution Radar. The feed is a multimode monopulse tracking feed employing a multiflare horn and is capable of transmitting a power level of 800 KW at 50% duty.

INTRODUCTION

The feed required for the 120 foot diameter high resolution radar is shown in figure 1, where a single multimode horn is used in a cassegrain configuration to generate sum, azimuth, and elevation signals. The feed must be capable of transmitting very high power (800 KW at 10 GHz) and must exhibit very good control of amplitude and phase signals over a 10% bandwidth.

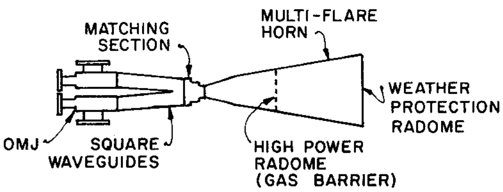

FIGURE 1

FEED DIAGRAM

HORN DESIGN

The first of three horn designs considered was the stepped input horn which can generate the proper beamshape at a single frequency and fairly good beamshape over about a five percent bandwidth. However, due to the excessive length of the required horn, over the ten percent bandwidth the degradation of the pattern at the band edge was too severe to consider this design. The second design was a corrugated horn which has the desired pattern characteristics but has unknown performance at very high power. The corrugated horn design was rejected because of the risk of high power arcing. The final design selected is the multiflare horn (figure 2) which has better bandwidth characteristics than the stepped horn and does not have the high power handling risk of the corrugated horn.

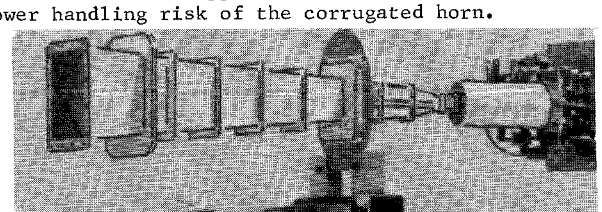

FIGURE 2

MULTIFLARE HORN

The better bandwidth characteristics of the multiflare horn are a direct result of the beamshaping mode being generated at a point where the horn has a large cross section, thereby minimizing differential phase shift. The development of a multiflare horn was based on the methods described by Dr. S. B. Cohn in his article "Flare-Angle Changes in a Horn as a Means of Pattern Control"[1]. The approximate analysis given by Dr. Cohn was expanded upon and incorporated into a computer program for analysis of multiflare horns. A synthesis driver was then added to the computer program so that horn designs could be synthesized and an initial design was tested which pointed out errors in the analysis program which were corrected. Further iterations with the synthesis program brought out more problems in the analysis and methods to correct them were found. The final horn design was synthesized by the computer and built to the computed dimensions. This horn has measured radiation patterns which are nearly identical to the computed patterns of the final breadboard horn with the computed patterns superimposed in dashed lines. Each of these figures show both the E and H

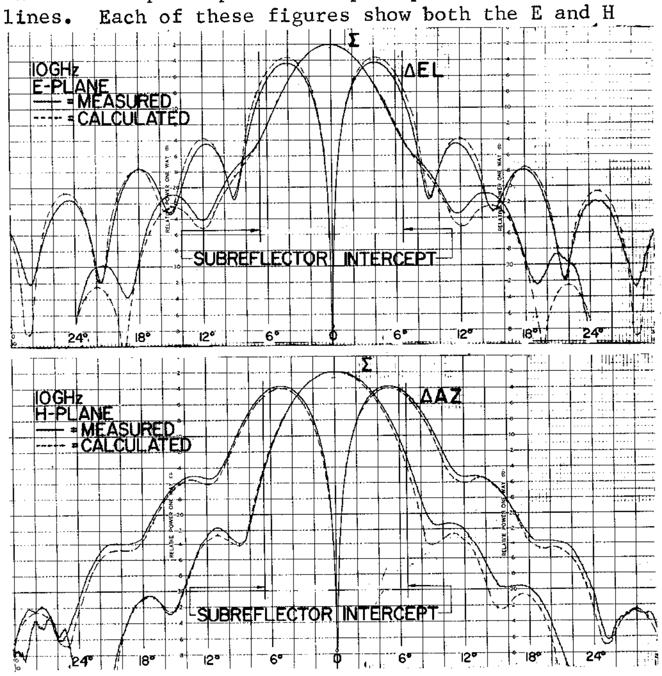

FIGURE 3

MEASURED AND CALCULATED PATTERNS

plane pattern for each difference channel, and illustrates the close agreement between measured and calculated radiation even out to the low level sidelobes. Figure 4 shows a comparison between the calculated and measured contour plots of the sum channel at 10.0 GHz.

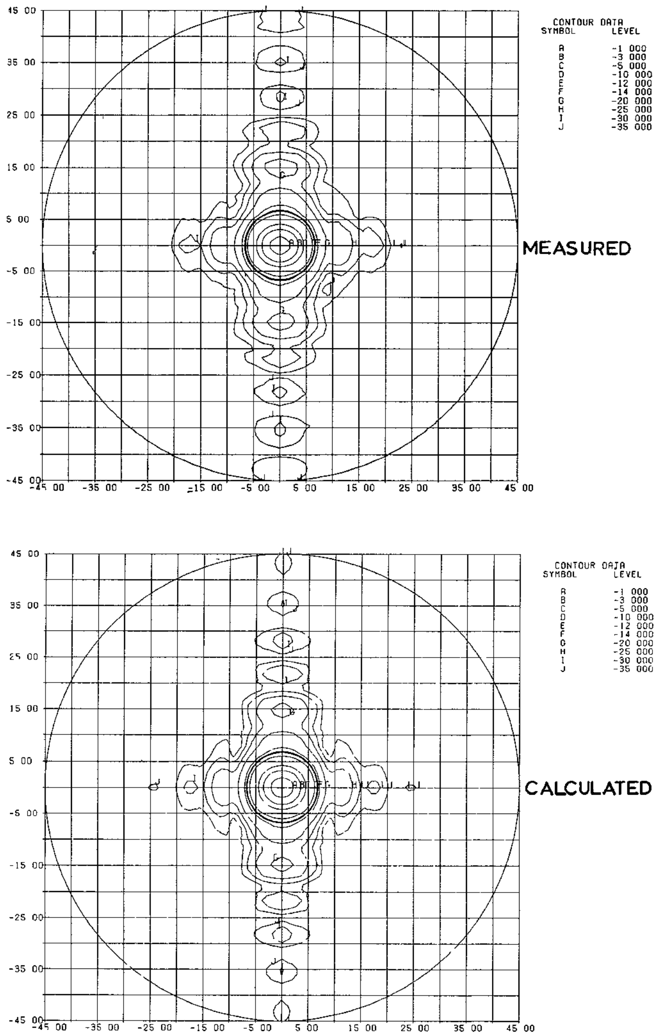

FIGURE 4

MEASURED AND CALCULATED MULTIFLARE

HORN CONTOUR PLOTS

During the synthesis of the multiflare horn two major goals were assigned to the computer program which attempted to synthesize the design of a horn meeting both of these goals. The first goal was low sidelobe (spillover) energy; the second goal was a circular beam over the subreflector intercept angle with a subreflector intercept level of 12 $\pm$2 dB between 9.5 and 10.5 GHz, and 12 $\pm$0.5 dB at 10.0 GHz. The total length of the horn was also constrained so that it would be consistent with the existing cassegrain geometry. The synthesis program could not successfully generate a horn design which fully satisfied both goals so a compromise became necessary in order to realize a design. The only goal which is not met in the final design is the intercept taper at the bottom of the band (9.5 GHz) which was approximately 9.5 dB in the H-plane. The achievement of low sidelobe energy is illustrated in figure 5 which shows a comparison between contour of the multiflare horn, a four horn feed, and a simple pryamidal horn. The spillover efficiencies indicated on figure 5 as well as the contour maps themselves show that the multiflare horn has lower spillover energy than either the pyramidal horn or the four horn feed.

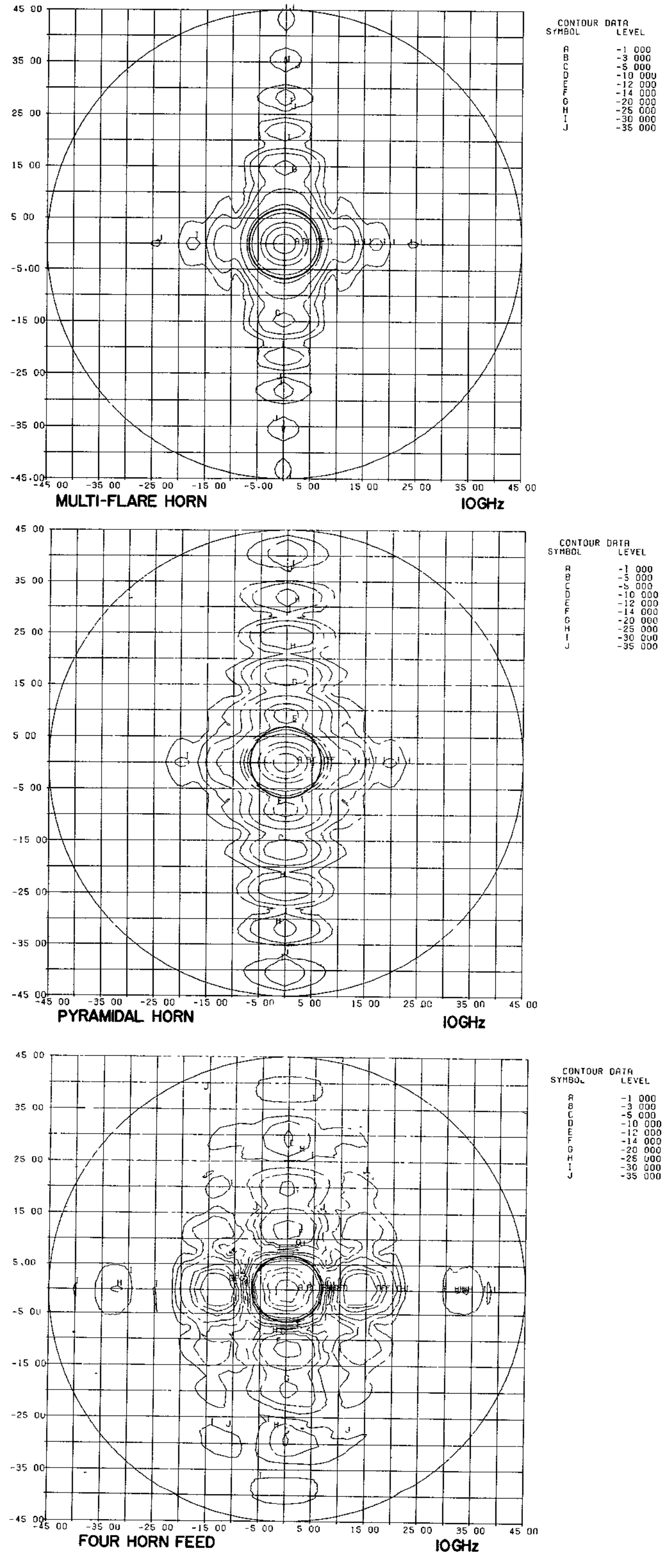

FIGURE 5

SIDELOBE ENERGY COMPARISON

Figure 5 also illustrates the beam circularity of the multiflare horn compared to a pyramidal horn. The pyramidal horn has elliptical contours near the subreflector intercept angle whereas the multiflare horn has nearly circular contours. The four horn feed has nearly square contours near the subreflector intercept because its pattern shape depends heavily on the array factor of the four horns. It is also the array factor which makes the spillover efficiency very low. The multiflare horn has both better beam circularity and higher spillover efficiency than either the pyramidal horn or the four horn feed.

MATCHING SECTION

In order to launch the sum and both tracking channels into a single horn, a multimode matching section was employed. The matching section consists of a junction between four square output waveguides and a single larger square output waveguide with a square waveguide step transformer in between adjusted to match the TE_{10}, LSE_{11} and TE_{20} modes into the horn when appropriate excitation is impressed on the four input waveguides.

OMJ

Each of the four square input waveguides to the matching section is fed by an orthomode junction (OMJ) so that either vertical or horizontal polarization may be launched into each square waveguide. The OMJ's also provide circular polarization by using quadrature excitation of both ports of each OMJ. There are basically two methods of designing an OMJ. The first method consists of making an abrupt junction and using irises to match the junction. The second method consists of designing each arm as a step transformer which is matched without the necessity of irises. A combination of these methods can also be used. Irises were considered undesirable for three reasons; first, because irises are often thin, the probability of high power arcing is very high; second, due to the high average power, cooling of irises would be very difficult; and third, the phase characteristics of a number of irises used for matching tend to cause the transmission phase to deviate from a normal waveguide curve whigh makes phase matching of the orthogonal arms difficult. The transformer OMJ design has none of these undesirable characteristics and therefore was used for the multiflare design. The two arms of the OMJ were synchronously designed as two four-section maximally-flat transformers. The VSWR of these units were less than 1.1:1, the isolation exceeded 45 dB and the phase ripple was less than $\pm 1^{\circ}$.

COMPARATOR

In order to impress the necessary excitation at the inputs of the four OMJ's to launch the sum and both tracking channels in each polarization, two orthogonal test comparators were constructed. One comparator is used for vertical polarization and the other comparator is used for horizontal polarization.

COOLING

The requirements for very high power necessitate that all of the feed components be adequately cooled. In order to provide this cooling, all of the feed components are made of electroformed copper with copper tubes attached to the outside of the walls for water cooling. The four square waveguides which go from the OMJ's to the matching section (quad flaring section) are encased in a water bath to provide adequate cooling as the four waveguides come together as shown in figure 6. The smaller section of the multiflare horn below a five-inch cross section is also water cooled. The large section of the horn where the wall currents are much smaller is fabricated of aluminum and is not water cooled in order to reduce the weight of the feed.

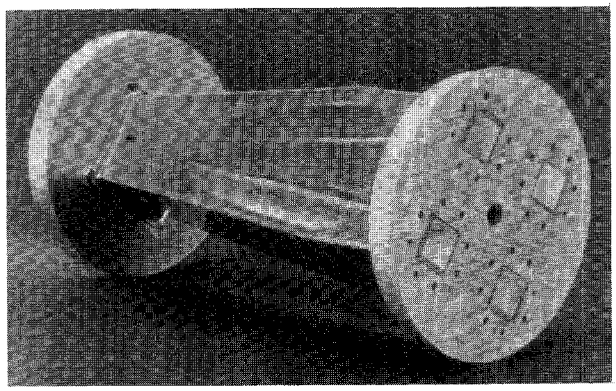

FIGURE 6

QUAD FLARING SECTION

FEED RADOME

At a five-inch cross section in the horn, a radome designed for high power is used to allow the system to be pressurized with a gas such as SF_6 to increase the peak power capability of the system. A study of radome materials was done to determine the best material for the high power radome. A fuzed quartz cloth, teflon laminate, was used for the radome. Samples of this material were successfully tested to power levels in excess of 25000 w/in^2.

CONCLUSIONS

The feed was assembled and tested, and the feed efficiency computed from measured data was 72% at 9.7 GHz and 10.3 GHz and 78% at 10.0 GHz. The feed efficiencies consists of the products of spillover efficiency, illumination efficiency, and phase efficiency. The spillover efficiency includes feed loss and all energy not reaching the subreflector in the proper polarization. The gain ripple achieved was less than .3 dB and the phase ripple was less than 2°. The components of this feed have been high tested to assure the high power requirements have been attained.

REFERENCES

1. S. B. Cohn "Flare Angle Changes in a Horn as a Means of Pattern Control", Microwave Journal, October 1970, pp 41-46.

ACKNOWLEDGEMENTS

The authors wish to extend their thanks to Mr. C. Jones, Dr. J. Ruze, Mr. W. Fitzgerald, and Mr. H. Kusunoki for their invaluable assistance in the course of the development of this feed.