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3.2 MILLIMETER WAVE TRANSMITTER TUBE.(U)
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Research and Development Technical Report

DELET-TR-78-3015-2

# 3.2 MILLIMETER WAVE TRANSMITTER TUBE

J. A. Davis
Hughes Aircraft Company
Electron Dynamics Division
3100 West Lomita Boulevard
Torrance, California 90509

MARCH 1980

Second Interim Report for Period 1 February 1979 - 31 May 1979

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Considerable progress has been made in the design of the 100 W peak (50 W avg.) power TWT, designated the 982H. The basic rf circuit has been tentatively designed, subject to further evaluation by testing with scaled x-band parts. The windows, taper (transformer), collector, and magnets have been designed. The electrical design of the gun is nearly complete, and the mechanical layout must still be prepared.

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## LIST OF ILLUSTRATIONS

## 1. INTRODUCTION

The objective of this program is the development of 3.2 millimeter wave tubes having the smallest possible volume, lowest possible weight, and the lowest potential production cost without compromise of performance. The tube objectives are:

| | |
|---|---|
| Peak RF power output | 1 kW (maximum) |
| | 100 W (minimum) |
| Average RF power | 50 W (liquid cooled) |
| | Concurrent with 100 W peak |
| | 10 W (air cooled) |
| | Concurrent with 1 kW peak |
| Center frequency | 93.75 GHz |
| Instantaneous bandwidth | 2 GHz |
| Small signal gain | 60 dB |
| Large signal gain | 50 dB |
| Pulse length | 25 μs max, 1-10 ns objective |
| Pulse rise time | 1 μs |
| PRF | 20 KHz max |
| Length | approx 61 cm |
| Width | 10 cm |
| Height | 10 cm |
| Weight | 7 kg |

The program consists of two parallel phases, the first being concerned with the 100 W TWT and the second with the 1 kW TWT.

Considerable progress has been made in the design of the 100W peak (50W avg.) power TWT, designated the 982H. The basic rf circuit has been tentatively designed, subject to further evaluation by testing with scaled X-band parts. The windows, taper (transformer), collector, and magnets have been designed. The electrical design of the gun is nearly complete, and the mechanical layout must still be prepared.

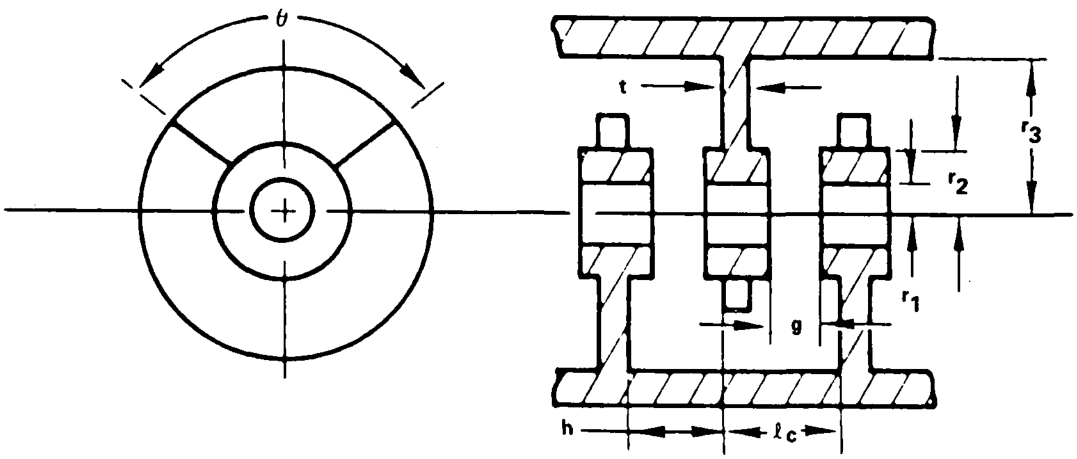
A thicker (0.020") vacuum sheath will be used on this tube, rather than the normal 0.005" thick sheath which has been used on most Hughes EDD mm-wave TWT's to date. The thicker sheath will give greater structural stability to the circuit. Also, the magnetic pole pieces will be brazed directly to this sheath, creating precise and secure alignment of the magnets to the rf circuit.

## 2. RF CIRCUIT DESIGN

The tentaive RF circuit design is shown in Figure 1, along with the scaled X-band parameters. The computer predicted dispersion curve is shown in Figure 2. The center frequency of the hot band interacts with the beam at a value of $\beta L/\pi = 1.42$. Because of the magnetic focusing constraints, a relatively large beam hole of 0.019" has been chosen, giving a relatively large $\delta$ a of 1.65.

The scaled X-band parts have been ordered. The circuit will be cold matched at X-band, when the final values of ferrule gaps and aperture angles will be determined. At W-band there will be adjustable ferrules and backwalls in the match cavities, so that fine tuning of individual circuits will be possible. Also at W-band, a selection of termination ceramics with different slopes will be available. To optimize the cold reflection match.

G6619




| | W-BAND | [SCALE FACTOR: $\frac{0.900}{0.100}$ = 9.00] | X-BAND |
|---|---|---|---|
| $2r_1$ | 0.019 INCHES | | 0.171 INCHES |
| $2r_2$ | 0.030 | | 0.270 |
| $2r_3$ | 0.06276 | | 0.56484 |
| $\theta$ | 125° | | 125° |
| $l_c$ | 0.0247 | | 0.2223 |
| h | 0.0177 | | 0.1593 |
| t | 0.007 | | 0.063 |
| g | 0.00987 | | 0.089 |
| CIRCUIT O.D. | 0.170 | | |

FIGURE 1 TENTATIVE CAVITY DESIGN

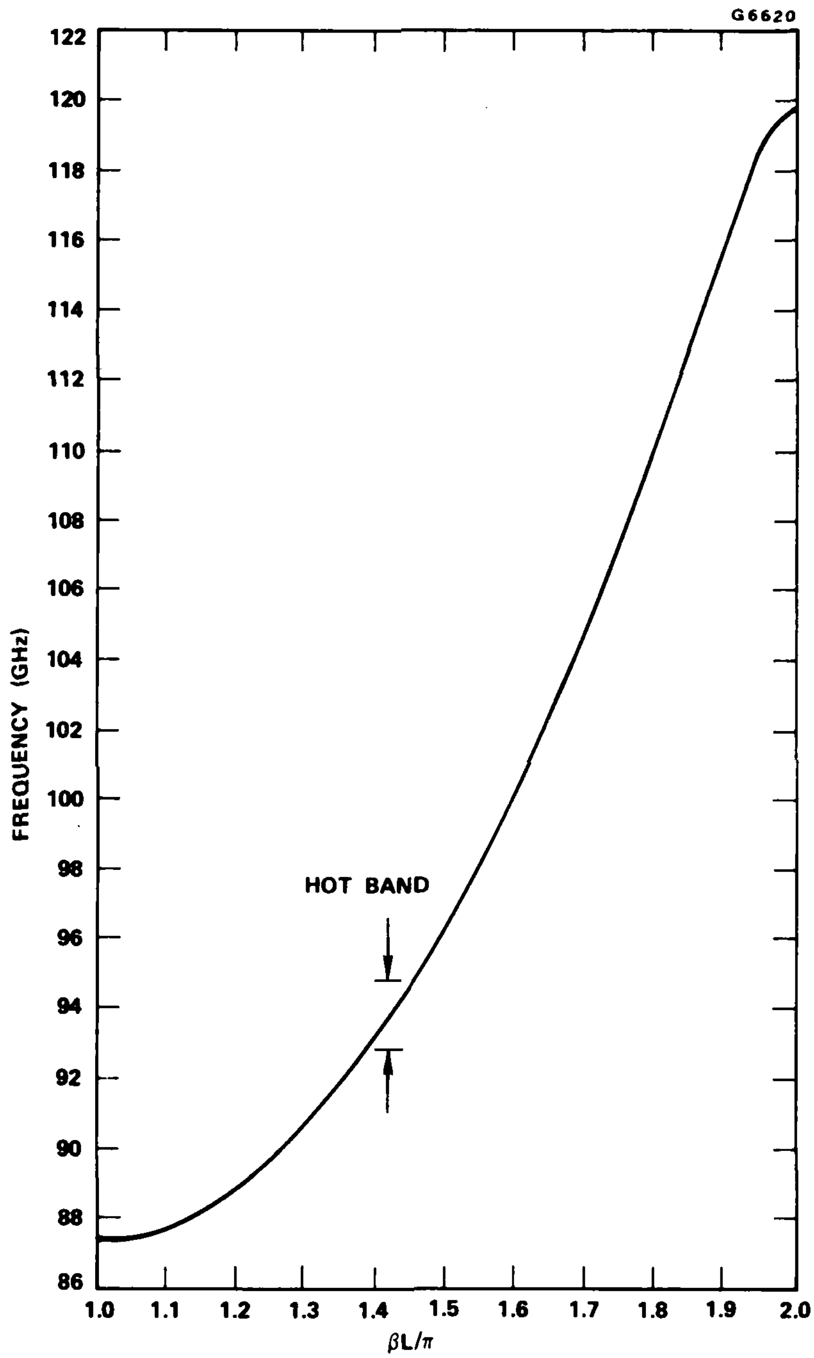



FIGURE 2. DISPERSION CHARACTERISTIC

## 3. MAGNET DESIGN

The periodic permanent magnet (PPM) design is constrained by 1) the magnetic field magnitude as predicted by the Ambose computer program, which predicts the beam focusing of the electron gun with the periodic magnet structure 2) the scallop wavelength, determined also by the Ambose program in which the ratio of scallop wavelength to magnetic period must be greater than 1.2, 3) the minimum pole piece I.D., which must be larger than the vacuum sheath O.D., 4) the constraint that the iron pole pieces must not be saturated, and 5) the fact that the transformers both take up room that cannot be filled by magnets and the resulting magnetic void allows leakage flux which further substracts from the axial field available at the coupler location.

Samarium cobalt magnets will be used, since they deliver the greatest magnetic field per unit volume of any readily available material.

Vacuum melted electrolytic iron pole pieces will be used, rather than cold rolled steel, because iron saturates at about a 2 kilo-Gauss higher field.

The basic magnet design is shown in Figure 3. The iron pole pieces are brazed directly onto the 0.020" thick vacuum sheath. The pole pieces are ferruleless, which allows for a simpler pole piece design at no sacrifice in magnetic field. The pole pieces are of a smaller O.D. than the magnets, because it has been empirically shown on other tubes that we get a greater field on axis than if the pole pieces and magnets are of the same diameter, presumably because of a reduction in the fringing flux at the O.D. The Amboss program predicts a scallop wavelength of 0.60 and the magnetic period chosen is 0.436.

The gun and collector pole pieces are made of iron to magnetically shield the gun and collector. Because these pole pieces are of greater diameter

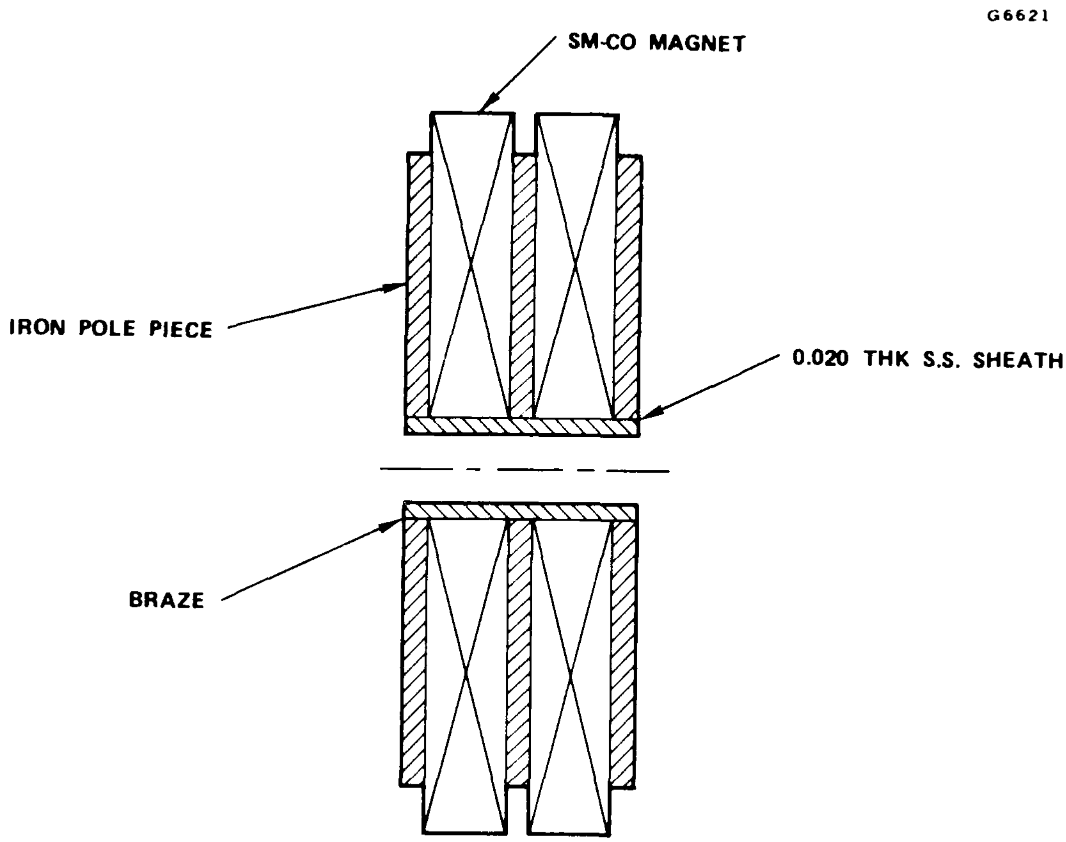



FIGURE 3 MAGNET DESIGN

than the other pole pieces, the fringing flux at the O.D. is greater than normal, and it is necessary to increase the thickness and perhaps the diameters of the magnets at the ends. In order to keep the magnetic period constant, ferrules will be put on both the gun and collector pole pieces. A computer program has been written to calculate the magnet thickness required.

Because this tube has a beam scraper, the input transformer (actually a taper) is not adjacent to the gun pole piece. Since it is desirable to keep the magnetic period constant, it is not possible to make the magnets at the input transformer thicker to compensate for the reduction in magnet volume and the additional fringing flux through the transformer. The magnet diameter can be increased, if necessary. It is our intention to experiment with the beam tester to determine the magnet diameter and pole piece thickness required in this region, using different iron shims and different diameters and thickness magnets. A larger diameter magnet than standard complicates the package design, especially cooling design, so an unnecessarily large diameter should be avoided if possible. However, a computer program has been written to calculate the fields necessary, and it shows that the standard 1.5 inch diameter magnet would be adequate.

## 4. WINDOW DESIGN

A block window with beryllia ceramic will be used on the TWT. The beryllia will be metallized and brazed into elkonite, which matches the thermal expansion of the beryllia.

Irises with circular holes are spaced symmetrically on each side of the ceramic block. The spacers between the ceramic and iris are also elkonite, to minimize distortion during braze.

The ceramic thickness, iris size and iris to block spacing were determined from a computer program which calculates the reflectance, given the window parameters. This program has recently been rewritten to loop, so as to automatically design a window whose reflection closely matches the magnitude of a third order Chelyshev polynomial. This is accomplished by having the computer minimize the sum of the reflections at the calculated three Chelyshev zeroes, by varying the block thickness, iris separation and iris opening.

Figure 4 shows a plot of the theoretical percent reflectance versus frequency. It is not possible to get a good match over the entire cold band (87.3 to 119.3 GHz), but the region from just above lower cut-off to 106 GHz has a reflectance of no more than 2.7%. The rf circuit has sufficient loss from the skin effect that no oscillation problems are expected, even at the frequencies where the window is not a good match.

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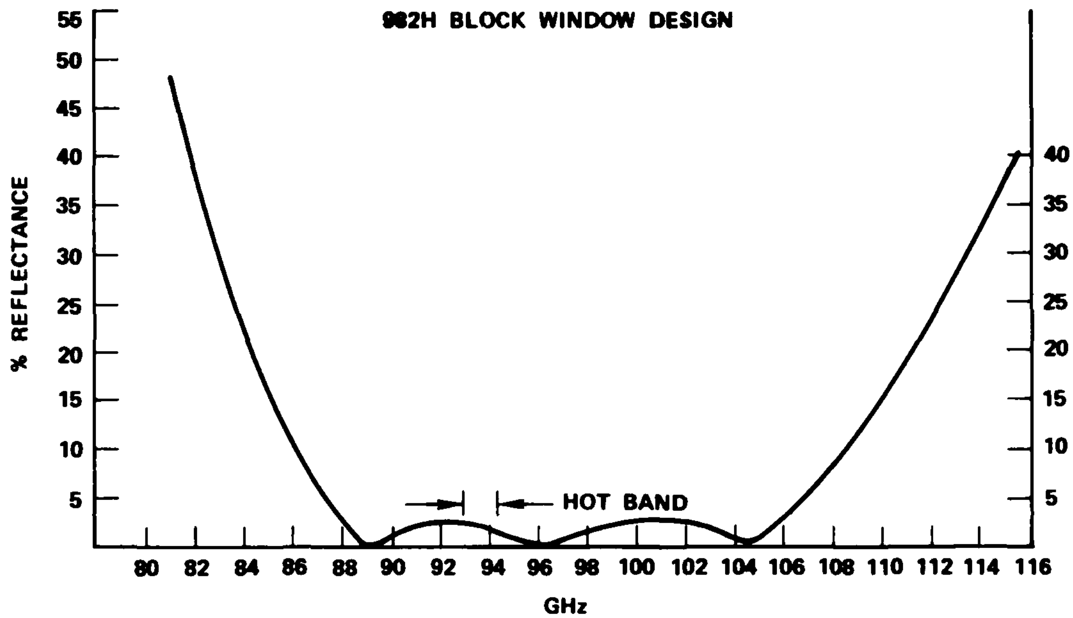


FIGURE 4 WINDOW REFLECTANCE

# 5. ELECTRON GUN

The electron gun design is currently in progress. An aperture grid is to be added to the electrical design. The beam diameter versus distance for the gun without aperture grid is shown in Figure 5. 99.5% of the beam current is within the dotted line ($R_{99.5}$) and 95% of the current is within the solid line ($R_{95}$). One would therefore expect about 98.5% transmission during d.c. operation.

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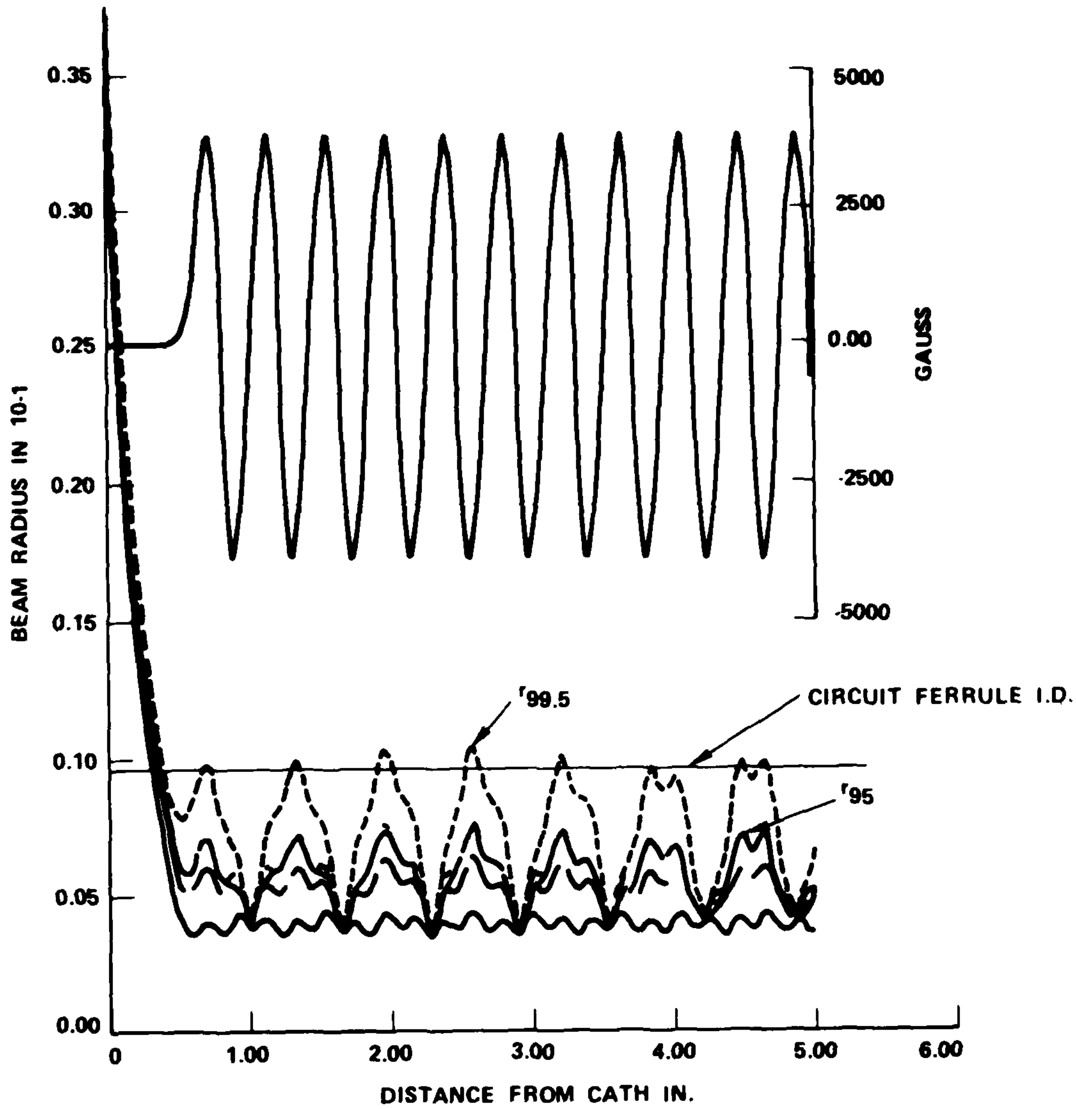



FIGURE 5. AMBOSS COMPUTER PROGRAM TO OPTIMIZE THE THERMAL BEAM GEOMETRY AND FOCUSING.

## 6. TAPERS

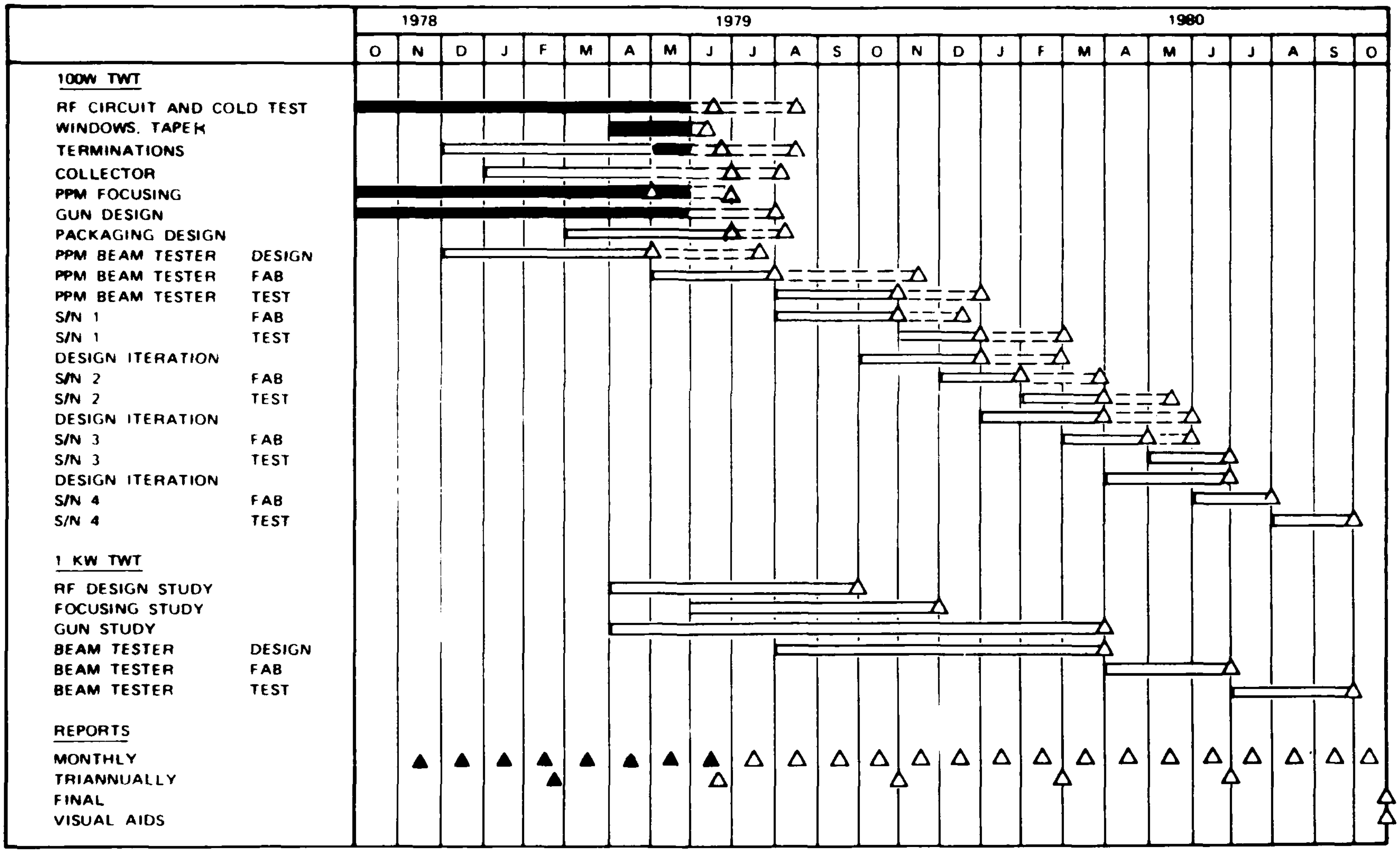
Instead of stepped transformers, tapers will be used. Tapers should be broader band, less susceptible to dimensional changes, and more economical to manufacture.

## 7. COLLECTOR

The collector will be a refinement of an existing design. It has a beryllia ceramic for voltage standoff, and is of such a design that the original liquid cooled version can later be modified to air cooling with only minor changes.

# 8. PROGRAM SCHEDULE

PROGRAM SCHEDULE



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UNIVERSITY OF UTAH
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