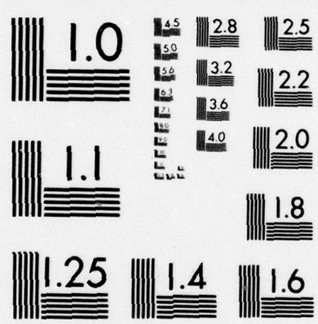
AD-A063 329 HUGHES AIRCRAFT CO TORRANCE CALIF ELECTRON DYNAMICS DIV F/G 9/1
LINEAR 1 KW MULTITONE TROPOSCATTER TWT.(U)
DEC 78 A L ROUSSEAU DAAB07-77-C-2713
UNCLASSIFIED EDD-W-07564 DELET-TR-77-2713-3 NL

1 OF 1
AD
A063329

END
DATE
FILMED
3-79
DDC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

LEVEL II

(12)

Research and Development Technical Report

DELET-TR-77-2713-3

LINEAR 1 kW MULTITONE TROPOSCATTER TWT

A. L. ROUSSEAU

HUGHES AIRCRAFT COMPANY
Electron Dynamics Division
3100 West Lomita Boulevard
Torrance, California 90509

December 1978

Interim Report for Period 1 May 1978 – 31 August 1978

Approved for Public Release: Distribution Unlimited.

Prepared For: Electronics Technology and Devices Laboratory

ERADCOM
US ARMY ELECTRONICS RESEARCH AND DEVELOPMENT COMMAND
FORT MONMOUTH, NEW JERSEY 07703

NOTICES

Disclaimers

The citation of trade names and names of manufacturers in this report is not to be construed as official Government indorsement or approval of commercial products or services referenced herein.

Disposition

Destroy this report when it is no longer needed. Do not return it to the originator.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER DELET-TR-77-2713-3	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) LINEAR 1 kW MULTITONE TROPOSCATTER TWT.		5. TYPE OF REPORT & PERIOD COVERED Interim Report 3, 1 May [redacted] to 31 Aug[redacted] 78
		6. PERFORMING ORG. REPORT NUMBER W-07564
7. AUTHOR(s) A. L. Rousseau		8. CONTRACT OR GRANT NUMBER(s) DAAB07-77-C-2713
9. PERFORMING ORGANIZATION NAME AND ADDRESS Hughes Aircraft Company Electron Dynamics Division 3100 West Lomita Boulevard, Torrance, CA 90509		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 1L7 62705 AH94 B1-12
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Electronics Research & Development Command ET&D Laboratory, ATTN: DELET-BM Fort Monmouth, New Jersey 07703		12. REPORT DATE DEC[redacted]R 1978
		13. NUMBER OF PAGES 13
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) 19p.		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release
Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

High Power TWT
Intermodulation Distortion
Depressed Collector
High Efficiency Tube

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report covers the third triannual effort of a Research and Development program to design, construct, and test an advanced, high efficiency traveling-wave tube designed to amplify multiple signals while minimizing any mixing products which result from non-linear operation. The tube will be operated in the linear region below saturation; tube efficiency will be enhanced by means of a four-stage, depressed collector.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

402 638

20. During the report period, parts for the electron gun were received. The assembly tooling for fabrication of the gun was designed and ordered.

Circuit parts were obtained and matching of the RF circuit was started.

The mechanical design of the four-stage collector was continued. A successful electrode-to-ceramic braze was accomplished.

Design of the overall packaging was continued.

The program has been proceeding very slowly during the last period because of the limited funding and the unexpectedly high cost of the collector.

PURPOSE

The purpose of this program is to design, construct, and test an advanced high efficiency traveling-wave tube in accordance with U.S. Army Electronics Command, Beam, Plasma and Display Technical Area Guidelines "MW-114 for the Linear 1 kW Multitone Troposcatter Traveling Wave Tube", dated 20 October 1976. This tube will be designed to amplify multiple signals while minimizing any mixing products which result from non-linear operation. It will operate at a power output of 1.0 kW CW with a gain of 40 dB over the 4.4 to 5.0 GHz frequency band. It will be operated in the linear region below saturation. Overall tube efficiency will be enhanced by means of a multiple-stage, depressed collector. The tube will use a coupled-cavity interaction circuit with integral permanent magnet beam focusing. Air cooling is an objective.

The program calls for the delivery of one exploratory developmental model representative of the work accomplished under the development effort. The length of the program is twelve months.

TABLE OF CONTENTS

1 INTRODUCTION

The basic objective of the present program is to demonstrate an optimum traveling-wave tube (TWT) design for applications in tactical troposcatter communications systems. The design of this tube will be based on the data presented in the Research and Development Technical Report ECOM-75-1283-F. The primary design concept is to operate the tube below saturation in order to achieve the low intermodulation (IM) requirements. To achieve the required performance characteristics the tube will be operated approximately 6 to 7 dB below saturation. At the rated power of 1.0 kW minimum, the basic efficiency of the tube will be approximately 4 percent. To improve the overall efficiency of the tube, a four-stage depressed collector will be used to recover most of the kinetic energy in the spent beam. The original design study indicated that the overall efficiency can be increased to a minimum of 25 percent by using this technique.

The specification for the multitone troposcatter TWT is presented in Table 1.

Periodic permanent magnet (PPM) focusing of the electron beam and air cooling are objectives of the tube design because the overall efficiency will be greater if PPM focusing is used in place of conventional solenoid focusing with the attendant solenoid power supply and air cooling will make the tube more compatible with existing troposcatter transmitters. Therefore, these features are being used for the multitone tube.

The theoretical electrical characteristics of the tube were described in detail in the earlier report, ECOM-75-1283-F. The purpose of the

TABLE 1

SPECIFICATION FOR MULTITONE TROPOSCATTER TWT 673H

Electrical Requirements:	
Frequency Range	4.4 - 5.0 GHz (Min)
Power Output CW	1 kW (Min)
Gain	40 dB (Min)
Instantaneous Bandwidth (-1 dB)	15 MHz (Min)
Beam Voltage	-26 kV (Max)
Beam Current	1.5 A (Max)
Efficiency (Note 1)	25% (Min)
Intermodulation (Note 2)	-20 dBC
Output Load VSWR	1.5:1 Max
Focusing	PPM (Objective)
Life	10,000 Hrs. (Objective)
Mechanical/Environmental:	
Size	To Be Determined (TBD)
Weight	To Be Determined (TBD)
Cooling	Air (Objective)
RF Input Connector	Type N Coax
RF Output Connector	WR-187 Waveguide/UG-149/Flange
Altitude (Operating)	3,100 Meters
Ambient Temperature (Operating)	$-50^{o}C$ to $55^{o}C$
Mounting (Operating)	0 to 15^{o} from Vertical
Shock (Non-operating)	50 G, 1 msec
Vibration (Non-operating)	5 to 55 Hz 1.02 cm Amplitude 5 ± 0.5 Minutes

Note:

1. The overall TWT efficiency is defined as: RF output power divided by the sum of beam input power, cooling power, focusing power, and heater power. The tube shall be capable of meeting the efficiency specified under conditions where the IM products are within the specified limits with 4 to 16 signals applied to the input.

2. The intermodulation products requirement will be met over any 15 MHz band in the 4.4 GHz to 5 GHz frequency range. The 15 MHz band will be divided into sixteen adjacent equal bandwidth channels. Anywhere from 4 to 16 of the channels will be occupied by carriers. The total intermodulation power in any occupied channel shall be 20 dB below the carrier in that channel. The carrier output power of all the occupied channels shall total 1 kW.

present program is to construct a tube having the previously determined design parameters and measure its operating performance. This effort consists chiefly of the following areas:

a. An electron gun will be scaled to the required beam size, area convergence, and perveance and mounted in an existing isolated anode support structure.

b. The RF interaction circuit and integral PPM focusing structure will be designed. This includes determining the final circuit dimensions to give the required phase shift characteristics, providing adequate circuit loss for stability, and matching the circuit to internal sever terminations, an input coaxial coupler, and an output waveguide step transformer and window.

c. The mechanical design of the four-stage depressed collector will be accomplished, taking into account the voltage standoff and thermal dissipation requirements, using the electrode configuration that had been determined previously.

d. The overall packaging and cooling structure of the tube will be designed.

e. The experimental tube will be fabricated and tested.

During the third triannual period of the program the fixtures for fabricating the electron gun were designed and ordered. The parts are available for construction of the gun during the next period.

Parts for the RF circuit were obtained and matching of the circuit waveguide couplers was started.

The mechanical design of the collector was continued. A final configuration, which is compatible with the thermal requirements of the tube has been developed. The detail design of the assembly fixturing remains to be done.

2 ELECTRON GUN

The design of the 238B electron gun was described in the earlier interim reports. It is a convergent flow gun with an area compression ratio of 16 to 1. It is designed to operate at a perveance of 0.33 micropervs with a cathode loading of 1.1 amperes per square centimeter. The gun will have an isolated anode for modulation. It will use an impregnated tungsten cathode.

During the present report period the assembly fixtures were designed and ordered. These fixtures consist of a braze fixture for alignment of the gun stem assembly, a gun locating fixture for setting the relative positions of the cathode, focus electrode and anode during assembly, and an RF brazing coil for attaching the anode to the completed gun.

The gun parts and assembly fixtures have been received. The gun will be fabricated and its performance will be checked in the demountable beam analyzer equipment during the next period.

3 INTERACTION CIRCUIT

As discussed in past reports, the basic circuit parameters for the 673H were chosen in the previous study program. During the present program, phase shift measurements were made on experimental circuit structures to obtain the exact circuit dimensions. Based on these measurements, the parts for the tube were designed and ordered. Cold test fixtures, to be used in matching the circuit to the external RF lines and to the internal sever teminations, were also designed and fabricated.

During the present report period, the copper laminated iron pole pieces were machined. The input and output circuit sections were stacked. Matching of the circuit was started. Adjustments of the resonant loss buttons were made by taking transmission measurements of the circuit sections. The loss buttons are installed in the circuit cavities to suppress unwanted oscillations. The resonant frequencies of the individual buttons are adjusted to provide loss in frequency bands at the upper cutoff of the fundamental operating band and at the slot mode (the mode associated with the resonant frequency of the coupling slot).

The matching of the circuit sections will be continued and completed during the next period. This work involves a series of reflection measurements, while adjusting the coupling slot size, the ferrule gap, and the back wall dimension of the cavities at each end of the circuit sections, to obtain the minimum RF reflection across the operating frequency band. Matches will be developed for the coaxial input line, the output waveguide, and both sides of the internal sever termination.

The gun and collector pole pieces were designed. They will be ordered during the next period.

4 COLLECTOR AND PACKAGE

The design of the four-stage depressed collector and the overall tube packaging was continued. The mechanical design of the collector has been the most crucial part of the present development program. The collector design is now complete except for the final configuration of the cooling fins and the assembly tooling.

A schematic layout of the collector is presented in Figure 1. The individual electrodes are brazed to metallized bands on the inside of the ceramic cylinder. The outside of the collector is at ground potential. The electrical standoff for the different electrodes is entirely within the vacuum envelope with the connections made through conventional high voltage feed-through assemblies. This design eliminates the problem of contaminating the insulating surfaces by deposits from the atmosphere during the air cooling of the collector.

Initially it had been planned that thin electrodes would be used that would not put a strain upon the metal-ceramic braze junctions. However, thermal calculations indicated that the temperature rise of the electrode tips would be much too high with thin electrodes. Consequently, the structure with thick electrodes, shown in Figure 1, was adopted. This design evolved after a series of electrode and ceramic shapes was investigated. Thermal calculations were made for the various interim configurations. The results for the final design are summarized in Table 2. Since the incident beam powers on the various electrodes change depending upon the particular tube operating parameters, three different cases are tabulated. These cases represent the highest electrode power that is expected under any operating condition (plus an extra safety factor of approximately 20 percent). Case I corresponds to operation of the low end of the frequency band, Case II will occur near the center of the band and Case III corresponds to the high frequency end. In all cases the RF drive level is that which gives a carrier to IM ratio

G4964

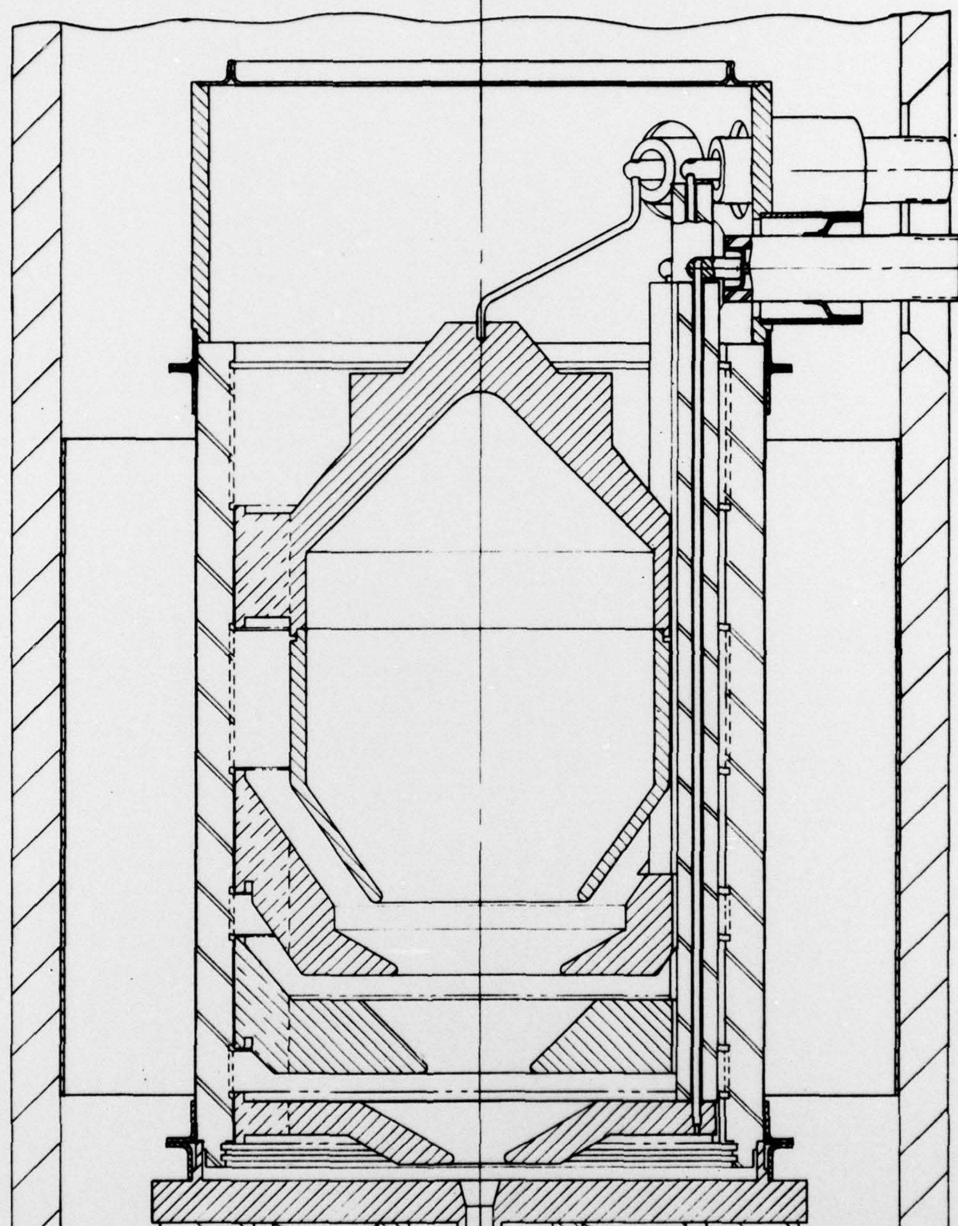


Figure 1 Schematic layout of four-stage depressed collector for 673H.

TABLE 2

MAXIMUM COLLECTOR ELECTRODE TEMPERATURES
FOR WORST CASE OPERATING CONDITIONS

		Beam Power Per Electrode (Watts)	Maximum Temperature of Electrode (°C)	
Case I	Electrode #1	**500**	**227**	
	Electrode #2	200	142	Low freq. end.
	Electrode #3	**2000**	**356**	
	Electrode #4	1000	262	
Case II	Electrode #1	400	194	
	Electrode #2	**2200**	**351**	Intermediate freq.
	Electrode #3	500	209	
	Electrode #4	1200	291	
Case III	Electrode #1	300	176	
	Electrode #2	1800	319	High freq. end.
	Electrode #3	700	232	
	Electrode #4	**1500**	**327**	

of 20 dB. (The beam current intercepted on the fourth electrode is actually higher when the tube is operated without RF drive applied. However, the power is not as high as for Case III, because with RF some of the electrons are accelerated and have greater energy than they would have without RF drive.) As can be seen, the highest calculated electrode temperature is 356°C on electrode number 3. This is a conservative design value. For the calculations an inlet air temperature of 38°C with an air flow of 400 CFM was assumed.

An unanswered question remaining is whether or not the collector-electrode assembly can be successfully brazed without cracking the ceramic insulator or leaving gaps at the braze interface. In order to relieve the stresses due to the differential thermal expansions of the ceramic insulator and the copper electrodes, a series of offset radial slots is cut into the outer diameter of the electrodes. This allows some flexibility in the electrodes without drastically reducing the thermal conductivity in the radial direction.

In order to establish the feasibility of the design, a dummy collector assembly was brazed. This assembly consisted of a short length of ceramic tubing, metalized on the ID, and one disc with machined slots to simulate the collector electrode. The disc was annealed copper, as it would be in the actual electrode. The first braze attempt was unsuccessful; many of the electrode fingers did not braze to the ceramic wall. It was felt that this was because the soft, annealed copper fingers were bent away from the wall, as the assembly was heated, by the braze material that was inserted between the fingers and the ceramic.

A second dummy electrode assembly was brazed. In this case, a thinner braze shim was used and greater care was taken in the placement of the braze material. The braze turned out very satisfactorily. Figure 2 is a photograph of the brazed, simulated collector assembly. All of the fingers are brazed to the metalized ceramic with continuous braze fillets. The assembly has been temperature cycled several times, both to the

E1976

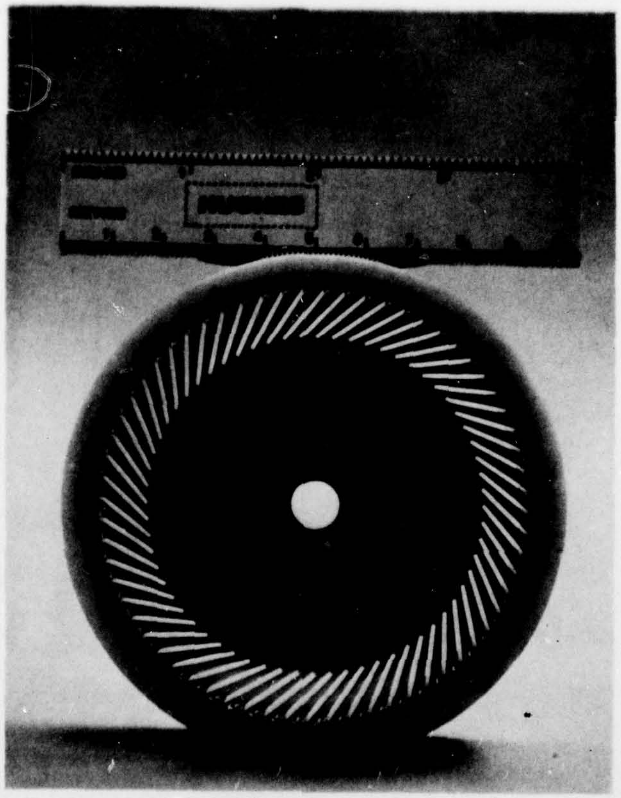


Figure 2 673H simulated collector electrode to ceramic brazed assembly.

bakeout temperature (500 to 525°C) and to the maximum expected operating temperature (200 to 300°C). There has been no evidence of cracking or pulling away of the copper fingers from the ceramic.

It is now felt that a practical design approach for the collector is available. It only remains to complete the design of the external air fins, design the assembly tooling, and order the parts. These steps and fabrication of the complete collector are planned during the next triannual period, together with completion of the design of the packaging of the tube.

5 PLANS FOR NEXT PERIOD

a. The 238A isolated anode electron gun will be fabricated and checked in the demountable beam analyzer. It will then be available for use on the 673H tube.

b. The design of the piece parts and assembly fixtures for the four-stage collector will be completed. Parts will be ordered. As parts are received, the collector will be assembled.

c. An evaluation will be made of the power required by the cooling fan and its effect on the tube efficiency.

d. Matching of the RF interaction circuit to the internal terminations, coaxial input line, and output waveguide will be accomplished. The circuit will be brazed.

e. The design of the external package will be completed. Parts will be ordered.