RESEARCH AND DEVELOPMENT
TECHNICAL REPORT ECOM-02340-6

C-BAND AND X-BAND DUAL-FUNCTION OSCILLATORS

QUARTERLY REPORT NO.6

by

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MAY 1968

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UNITED STATES ARMY ELECTRONICS COMMAND - FORT MONMOUTH, N.J. 07703

CONTRACT DA28-043 AMC-02340(E)

GENERAL ELECTRIC COMPANY
Tube Department - Owensboro, Kentucky

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OWENSBORO, KENTUCKY

FOR

U.S. ARMY ELECTRONICS COMMAND, FORT MONMOUTH, N. J. 07703

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ABSTRACT

The triode development phase, which had been concluded during the last report period, was reopened for evaluations at X-Band and for investigations toward improving performance on life.

Life tests at C-Band were terminated after 300 hours, and tabulated data for the ten samples is provided.

X-Band evaluations were continued for tubes having etched frame grid structures, and having unsupported and undamped, tensioned grid structures.

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STATEMENT OF PURPOSE

The purpose of this program is to develop two oscillators, one at C-band and one at X-band, which function sequentially as a transmitter and as a gated local oscillator in their respective bands. These oscillators should have the potential of low cost, design simplicity, and low power drain to meet the requirements of lightweight radar sets having a common transmitter and local oscillator stage.

TUBE DESIGN

The C-band life testing was terminated after 300 hours. The power output of the transmit function had degraded in excess of 3 db by the 200-hour test point. The output from the local oscillator had degraded in excess of 3 db by the 300-hour test point. A change in the intermediate frequency was also observed. The data for the ten sample life test is summarized in Table I.

The tubes were removed from the oscillator circuits and the tests for electrical characteristics were repeated. In some cases, the vacuum seals of the triodes were broken during the disassembly. This occurred because of thermal stresses involved in removal of circuit elements which had been soldered to the external metal contact of the triode. A loss of transconductance was detected on the remaining triodes. In addition, the pulse emission on these tubes was less. The characteristics of the triodes are provided in Table II. The performance before and after life testing has been indicated.

From this data, the reasons for the life test degradation appear to be associated with the loss of emission capability of the triode. A loss of emission could occur due to incomplete processing, due to insufficient activating agents, or because of the introduction of a contaminant or cathode poisoning agent.

The planning is nearly complete for a series of tests to evaluate the effect of changes in triode features. The test encompasses the addition of materials to the cathode surface as supplementary activating agents. It also assumes the copper-plating as a possible source of cathode poisoning agents. An evaluation is included to determine the effect of frame grid structures along with the grid structure having an interwoven damper wire. The planned triode construction features are outlined in Table III.

			CAVITY NUMBER									
Hours	**Function**	**Units**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0	Transmit	Po(W)	65	71	67	67	86	67	66	53	77	62
	L.O.	(mW)	102	166	67	208	96	250	72	100	41	117
	If	(Mc)	64	61	62	62.5	60	64	60	63	64	60
24	Transmit	Po(W)	52.5	53	37	50	82	50	62	60	62.5	31.5
	L.O.	(mW)	118	216	130	318	107	320	143	233	35	50
	If	(Mc)	62	61.5	59.5	62.5	64	64	58	61	65	62
50	Transmit	Po(W)	47	50	36.5	40	73.5	47	54	51.5	48.5	40
	L.O.	(mW)	90	160	91	266	90	300	86.5	193	N.O.	45
	If	(Mc)	63	65.5	61	67	63	61.5	61	64	---	134.5
75	Transmit	Po(W)	38.3	40	31.6	31.7	53.5	38	43.5	44	---	31.6
	L.O.	(mW)	93	192	66	266	83.5	290	133	167	---	36.7
	If	(Mc)	63	67	65	70	67	61	62	65	---	82.5
100	Transmit	Po(W)	40	41.8	33.4	35	60	42	46.5	48.5	---	35.0
	L.O.	(mW)	83.5	176	47	218	77	268	100	133	---	20.0
	If	(Mc)	66	67	68	74	68.5	67	64	68	---	87
200	Transmit	Po(W)	35	31.7	31.7	31.7	Arcing	35	37.5	38.3	---	26.5
	L.O.	(mW)	58.4	100	15	150	in	150	37.5	114	---	13.7
	If	(Mc)	65	75	74.5	76	Cavity	69	65	69.5	---	89
300	Transmit	Po(W)	25	20	31.7	21.6	---	30	30	26.6	---	16.7
	L.O.	(mW)	17.5	16.7	N.O.	25	---	13.6	N.O.	67	---	N.O.
	If	(Mc)	65	81	---	78.5	---	69.5	---	69.5	---	---

Note: N.O. means "No Oscillation"

TABLE I - RESULTS OF INITIAL LIFE TESTING

TABLE II. TRIODE CHARACTERISTICS FOR LIFE TEST SAMPLE

Lot #	Tube No.	Ip	Sm	μ	eg	ik	Cgp	
6AL1	1	16.5	21,100	80.5	28	2.1	1.0	Initial
		[illegible]	15,200	90.5	64	2.1	1.01	End of Life Test
6AL1	4	14.8	19,000	75.4	30	2.1	1.07	Initial
		10.7	15,000	82.8	62	2.0	1.07	End of Life Test
6AL1	6	19.2	21,300	61.0	27	2.0	1.01	Initial
		Air-Cracked Anode Seal						End of Life Test
6AL1	9	11.3	18,000	97.2	32	2.0	1.02	Initial
		8.2	13,800	104.5	56	2.05	1.04	End of Life Test
6AL2	1	12.5	18,600	97.6	28	2.0	0.93	Initial
		Air-Cracked Anode Seal						End of Life Test
6AL2	6	15.5	19,000	72.4	26	2.0	1.06	Initial
		Air-Cracked Anode Seal						End of Life Test
6AL2	7	17.7	20,100	59.5	32	2.1	0.975	Initial
		17.8	18,300	58.8	40	2.25	0.98	End of Life Test
6AL2	8	16.5	19,000	69.5	28	2.0	0.92	Initial
		13.6	15,500	69.6	>100	2.33	0.93	End of Life Test
6AL3	3	17.2	18,700	62.8	25	2.5	0.94	Initial
		13.7	14,800	67.2	54	2.3	0.95	End of Life Test
6AL3	5	14.3	18,800	72.2	30	2.1	0.95	Initial
		11.7	15,300	80.0	59	2.1	0.95	End of Life Test

TABLE III - TRIODE CONSTRUCTION FEATURES FOR C-BAND EMISSION CAPABILITY STUDY

Cathode Lid Material	Added Activator	Grid Structure
Molybdenum	Tungsten Powder	Interwoven Damper Wire
Molybdenum	Tungsten Powder	Frame
Molybdenum	Nickel Powder	Interwoven Damper Wire
Molybdenum	Nickel Powder	Frame
Molybdenum	Nickel and Tungsten Powders	Interwoven Damper Wire
Nickel (Radiation Heater)	None	Interwoven Damper Wire

X-band evaluations, which were reported in the last quarterly report, were continued. The triodes available for these evaluations were from four lots as shown in Table IV.

TABLE IV - FEATURES OF TRIODES USED FOR X-BAND EVALUATION

Lot Number	Construction Features
6AM1	Interlaced damper wire grid structure with a molybdenum cathode having a bonded heater
6AL3	Etched frame grid with a molybdenum cathode having a bonded heater
4CG8	Tensioned grid, undamped, with a molybdenum cathode having a bonded heater
C-6	Tensioned grid, undamped, with a nickel cathode having a radiation-type heater

X-band evaluations were performed on tubes from lot 4CG8. One tube from lot 6AL3 was tested. The transmit power output was low and the local oscillator function would not start at less than 300 volts. This tube contains the frame grid structure. The results of the X-band evaluations are shown in Table V.

TABLE V - RESULTS OF X-BAND EVALUATION

		Triode Characteristics				Oscillator Performance (Transmit Function Only)			
Lot #	Tube #	Cgp (pf)	Cin (pf)	Mu	Gm (μmho)	Po (W)	Ebb (Volts)	ip (A)	ig (A)
4CG8	59	0.99	2.20	65.5	21,200	110	1500	1.2	0.24
4CG8	67	1.08	2.20	58.6	21,300	215	1500	1.6	0.20
4CG8	74	1.23	2.31	49.3	21,100	92	1500	0.9	0.13
4CG8	87	1.05	2.27	57.9	20,700	51	1500	0.95	0.14
6AL3	10	0.97	--	57.5	19,600	22	1500	0.7	0.15

Several other triodes from lot 6AL1 and 6AL2 were tried in the oscillator, but their output power was found to be negligible.

CIRCUIT DESIGN

Oscillator DX-2

The variable oscillator (Oscillator DX-2,) which was mentioned briefly in Quarterly Report No. 5, was used in an attempt to isolate the reason for the low power output of some tube constructions operating at X-band frequencies. Oscillator DX-2 proved to be an effective tool for optimizing tubes of widely divergent characteristics.

Several tubes of different construction, but with approximately the same characteristics, as tested to standard specifications, were tested for output power at X-band frequencies. The output powers delivered by these groups of tubes ranged from a few watts peak power to over one hundred watts peak. The same lots of tubes were then checked for emission capability. At a point well over the standard test point, differences in the individual tubes became evident. The cathode current of some tubes would saturate, while the cathode current of others would increase until reaching the maximum allowable drive. It was also noted that the plate current to grid current ratio at high drive levels varied dramatically from a tube that operated well in the X-band frequencies to one that did not.

Oscillator DX-2 proved to be important for still other reasons. The feedback phase can be varied by changing the length of the cathode line. After the output power is optimized for a particular set of operating parameters, a slight variation in length of cathode line has a marked effect on the frequency of the local oscillator function while having only a minor effect on the frequency of the transmit function. Varying the length of the cathode line, then produces a change in the intermediate frequency of the dual function oscillator. In Oscillator DX-2 the intermediate frequency was varied smoothly from 20 Mcs to 100 Mcs. It should be noted here that this is not an independent adjustment, but it also affects the output power. This device can, however, be utilized effectively for trimming the intermediate frequency without adversely affecting output power. Since a variable line is a bulky device, as well as being mechanically unstable, it is desirable that the cathode line be varied electrically in a practical model. This approach seems feasible because of the very small adjustment required.

One additional observation was made while evaluating Oscillator DX-2. With fixed local oscillator and transmit voltages applied, the difference frequency changes by several megacycles as the transmit frequency is varied. This change in difference frequency is not constant from one tube construction to another, which is an indication that the resonant frequency of the grid-anode circuit does not track with the phase of the feedback signal. A special shorting choke was constructed for Oscillator DX-2 so that the resonant frequency of the grid-anode circuit could be adjusted independently of the feedback phase. The choke consists of conventional $\lambda/4$ choke section, with a slip finger contact to an intermediate section of line approximately 20% larger in diameter than that of the anode line, over which the intermediate line slips. Finger contacts are provided for RF continuity. Provisions were made to move the intermediate line without altering the position of the choke. As the end of the intermediate line is moved toward the anode of the tube, the average characteristic impedance of the grid-anode line decreases, thereby reducing the foreshortening of the resonant cavity caused by the output capacitance of the tube. The resonant frequency of the grid-anode cavity should increase as the intermediate section of line is moved toward the anode. Since the feedback phase angle also decreases as the shorting choke is moved toward the anode, the intermediate section of line could, with a proper set of dimensions, be ganged to the shorting choke so that the desired intermediate frequency tracking could be attained over the required tuning range.

When Oscillator DX-2 with the section of intermediate size movable line was tested, it was observed that the resonant frequency of the grid-anode cavity decreased as the end of the line was moved toward the anode. This indicates that the discontinuity capacitance is affecting the resonant frequency of the section to a greater degree than is the reduction of foreshortening. It may be possible to reverse the order of these effects by increasing the characteristic impedance of the grid-anode cavity, making the foreshortening more effective. This can, of course, be accomplished either by decreasing the diameter of the center conductor, or by increasing the diameter of the outer conductor. It is undesirable to reduce the diameter of the center conductor, since it would then be smaller than the anode stud and another discontinuity would result. Another factor not to be neglected is the possible increase in RF loss because of the smaller center conductor.

Since the grid sleeve functions as a center conductor for the grid-cathode cavity, as well as an outer conductor for the grid-anode cavity, the impedance of the grid-cathode cavity will be lowered if the impedance of the grid-anode cavity is increased by altering the diameter of the grid sleeve. Such a solution to the tracking problem causes an additional problem of reduced feedback (magnitude). Because of the low voltage operation required for the local oscillator function, it is necessary to increase the magnitude of the feedback.

Oscillator DX-3

The foregoing conditions of increased grid-anode cavity impedance and increased feedback can be simultaneously met by enlarging the body of the oscillator. This was done by designing a completely new oscillator, Oscillator DX-3, with all the variable parameters of Oscillator DX-2. The slot coupling was replaced by a probe and a coaxial connector, in order to eliminate the effect of the additional feedback path resulting from the high current points at the ends of the slot. The inner diameter of Oscillator DX-3 is 0.063 inches larger than that of Oscillator DX-2. Preliminary tests of Oscillator DX-3 were made using the same tubes that were checked in Oscillator DX-2. These tubes had a grid sleeve designed for use with Oscillator DX-2 soldered to the grid. The frequency of oscillation of Oscillator DX-3 could be varied from 10.5 Gc to 11.5 Gc. The starting voltage was observed to be just over 125 volts. This low starting voltage is an indication of the increased feedback. No further tests have been made on Oscillator DX-3, but initial results encourage further investigation.

Oscillator DX-4

In order to test the idea of a "trimmer" for the intermediate frequency of a dual function oscillator, in a more simplified form than the movable line of Oscillator DX-2, a fixed oscillator was built. This oscillator will be numbered DX-4. Oscillator DX-4 is an aluminum, fixed coupled, variable frequency oscillator with a waveguide flange output. Since the type is fundamentally that which will be the end product, variations and changes will be identified by the number following DX-4. The cathode line of oscillator DX-4 was intentionally made short so that a susceptance stub could be placed in the cathode cavity to electrically lengthen it. With a plate pulse voltage of 1500 volts and a local oscillator voltage of 300 volts applied, with the proper time phase relationships for dual function operation, a difference frequency of 48 Mcs was observed. By simply moving the capacitive susceptance closer to the cathode line, the different frequency was trimmed to 60 Mcs.

The difference frequency of 60 Mcs was set up at a transmit frequency of 9.4 Gc. As the transmit frequency was increased to 9.5 Gc using single knob tuning, the difference frequency changed by 8 Mcs. While the difference frequency can be reset to 60 Mcs by a change in local oscillator plate voltage, or by readjustment of the susceptance stub, it is desirable that the difference frequency remain relatively constant, not only to reduce the corrections necessary to keep the difference in the passband of an intermediate frequency amplifier, but also as an indication of proper tracking of the oscillator.

This observation substantiates the need for further investigation of Oscillator DX-3.

CONCLUSIONS

Tubes made with molybdenum cathodes having bonded heaters apparently degrade on life; the use of nickel cathodes may prove to be the solution to this problem.

The susceptance stub used to trim the intermediate frequency of the X-band dual function oscillator seems to operate satisfactorily.

More work is necessary on Oscillator DX-3 in order to optimize tracking of the oscillator parameters and to minimize the difference frequency variation across the tuning range.

RECOMMENDATIONS

No recommendations are made at this time.

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14. KEY WORDS	LINK A		LINK B		LINK C	
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Negative-Grid Triode						
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