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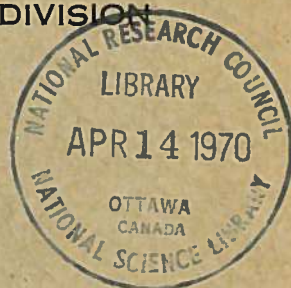
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A FREQUENCY MULTIPLIER FROM 100 KC TO 50 MC

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OTTAWA

JULY 1951

N.R.C. NO. 2483

A FREQUENCY MULTIPLIER FROM 100 KC TO 50 MC

D.W.R. McKinley and J.C. Swail

### ABSTRACT

This unit is used to multiply the 100-kilocycle output of a primary quartz crystal standard to 50 megacycles, taking special precautions to suppress unwanted subharmonic sidebands in the output by at least 70 decibels. The output power is approximately 1/2 watt. The unit requires 250 volts d-c, unregulated, at 140 milliamperes.

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## A FREQUENCY MULTIPLIER FROM 100 KC TO 50 MC

### Introduction

It is not difficult to multiply a low frequency by several hundred if the multiplying factor in each stage is kept as low as 2 or 3, and if a moderate amount of energy can be tolerated at the output frequency in the form of sidebands, or subharmonic modulation of the output carrier. However, if the primary frequency is 100 kc and the desired output frequencies are multiples of ten of this frequency, the smallest multiplying factors available are 2 and 5. In the development of a laboratory frequency standard for the VHF-UHF region there arose a requirement for a series of frequencies that were multiples of 50 Mc, without containing an appreciable intervening spectrum between the 50 Mc points — e.g., frequencies spaced by 100 kc, or multiples thereof. In another application it was desired to radiate a carrier on 150 Mc with a stability and accuracy of 1 part in 10 million to serve as a local-coverage standard-frequency transmission. All subharmonic sidebands on this carrier must be kept below 70 db. or more, to avoid interference with local communication stations.

### Description

In earlier attempts to achieve the required over-all multiplying factor of 500 the percentage of 100-kc and higher harmonic sideband energy in the high-frequency output was excessive. In the present arrangement the sidebands are reduced in amplitude by using "push-push" stages at the beginning of the chain, by inserting a 2-Mc quartz crystal filter at the 2-Mc stage, and by using several high-Q tuned circuits in subsequent stages.

In Fig. 1,  $V_1$  is a buffer amplifier used to drive the first push-push doubler stage,  $V_2$ . Input voltages from 0.1 volts to 100 volts may be accommodated by the potentiometer,  $R_1$ , which is normally set to saturate the buffer stage so that variations in the input level will not affect the operation of the multiplier unit. The coils  $L_1$ ,  $L_2$ ,  $L_3$  are each 380-microhenry inductances of 19-strand Litz wire, wound in the form of flat pies, each with a Q of about 120 over the 100-400 kc band. Coupling is not critical, as the primaries are tuned above the resonant frequency. Since the plate tank circuit of the  $V_2$  stage receives excitation on every cycle at 200 kc, rather than on every other cycle, the tank is more effective in filtering out the 100-kc fundamental.  $L_4$ ,  $L_5$ ,  $L_6$ , and  $L_7$ ,  $L_8$ ,  $L_9$  are transformers identical to  $L_1$ ,  $L_2$ ,  $L_3$ ; they are tuned to 200 kc and 400 kc, respectively, by the use of smaller condensers. The push-push stages  $V_2$  and  $V_3$  are both operated as class-A amplifiers. Test points,

T.P. 1, 2, and 3, are an aid to lining up the system, when they are connected directly to the Y-plate of a standard cathode-ray oscilloscope, using a linear sweep synchronized by the input 100-kc voltage.

The first quintupler stage,  $V_4$ , is operated push-pull class-C, which has the merit that the stage will create only odd harmonics.  $L_{10}$  is an Inductuner coil with an inductance of 40 microhenries and a Q of 250. A 2-Mc crystal is connected in a conventional bridge circuit across the 2-Mc tank, the balancing being done with  $C_{27}$ . A few r-f volts are impressed across the crystal but no heating or other ill effects are apparent.

The  $V_5$  stage is a straight-through amplifier which raises the 2-Mc signal level to drive the next quintupler stage, and at the same time the sideband rejection ratio is further improved by the addition of two more high-Q circuits at 2 Mc. The 100-kc and 200-kc sideband components are about 90 db down from the 2-Mc carrier at this point, and the 400-kc sidebands are about 60 db down. In the plate tank circuit of the next quintupler stage,  $V_6$ , the 8-Mc and 12-Mc sidebands are only 30 to 35 db down from the 10-Mc carrier, and further filtering must be added at 10 Mc. This is accomplished by the amplifier,  $V_7$ , using a grounded-grid tube (type-6J4). At this frequency no chokes are necessary in the heater leads of  $V_7$ . The plate voltage of  $V_7$  is lowered to about 90 volts to keep well within the tube ratings, and, because there is surplus driving power applied to the cathode, the output of this stage remains relatively constant for a wide variation in plate supply voltage. The additional Q introduced by the tank circuits  $L_{14}$ ,  $L_{17}$ , and  $L_{18}$  reduces all sidebands below 70 db at this point.

Another quintupler stage,  $V_8$ , multiplies the 10-Mc frequency to 50 Mc. A second grounded-grid stage,  $V_9$ , reduces the level of the 10-Mc sidebands to 70 db below the carrier. No shielding was required for this stage, and the shielding initially used for the previous grounded-grid stage,  $V_7$ , also proved to be unnecessary in practice. The power gain of these stages is about 2 or 3, which is so small that no oscillation troubles are encountered. The pentode amplifier,  $V_5$ , on the other hand, does need shielding of the plate tank, although this appears to be the only point in the system that requires special attention. Low-impedance link-coupling,  $L_{24}$ , to an output plug is used to supply the 50-Mc output power to other chassis.

Figs. 2 and 3 are photographs of the multiplier chassis.

The plate power supply requirements are 250 volts, unregulated, at 140 milliamperes, and the unit works well over the

range 200-300 volts. About 0.5 watt of 50-Mc power is available. There is no tendency toward oscillation anywhere in the system, and, if the 100-kc input fails, the 50-Mc output ceases. None of the adjustments is critical, and the unit has not required re-alignment since it was put into operation. The output is sufficient to drive a type-815 tripler stage followed by a push-pull amplifier stage using type-2C39 tubes, delivering 50 watts output on 150 Mc. As measured at 50 Mc with a SX-42 receiver, all sidebands are at least 70 db below the carrier, with the troublesome 100-kc and 200-kc sidebands being more than 90 db down.

\* \* \*

Mr. S.M. Panagapko constructed and wired the unit.

ITEM NO	DESCRIPTION	ITEM NO	DESCRIPTION
R1	50 K POT.	C30	500 pf (POST TYPE)
R2	2 K	C31	500 pf (POST TYPE)
R3	75K 1W	C32	25 pf A.P.C.
R4	2K 1W		
R5	1.2K 2W		
R6	1K 2W		
R7	1.2K 2W		
R8	1K 2W		
R9	47K 1W	L1	380 μH
R10	4.7K 2W	L2	380 μH
R11	1K 2W	L3	380 μH
R12	1K 2W	L4	380 μH
R13	47K 2W	L5	380 μH - SEE TEXT
R14	1K 2W	L6	380 μH
R15	270K 2W	L7	380 μH
R16	1K 2W	L8	380 μH
R17	18K 2W	L9	380 μH
R18	100 1W	L10	40 μH - SEE TEXT
R19	10K 2W	L11	3 TURNS ON L12 FORM
R20	10K 4.8W W.W.	L12	100 μH UNIVERSAL WOUND, LITZ WIRE
R21	27K 1W	L13	100 μH UNIVERSAL WOUND, LITZ WIRE
R22	1K 2W	L14	AIR SPACED INDUCTANCE
R23	18K 2W	L15	AIR SPACED INDUCTANCE
R24	100 1W	L16	AIR SPACED INDUCTANCE
R25	10K 4.8W W.W.	L17	AIR SPACED INDUCTANCE
R26	10K 2W	L18	AIR SPACED INDUCTANCE
		L19	AIR SPACED INDUCTANCE
		L20	AIR SPACED INDUCTANCE
		L21	AIR SPACED INDUCTANCE
		L22	AIR SPACED INDUCTANCE
		L23	AIR SPACED INDUCTANCE
		L24	AIR SPACED INDUCTANCE
			VALUES EXPERIMENTALLY OBTAINED
C1	.01mf CONDENSER	V1	6AG5
C2	.01mf	V2	12AU7
C3	.01mf	V3	12AU7
C4	200pf	V4	12AU7
C5	25 pf	V5	6AK6
C6	.01mf	V6	6AQ5
C7	300-1,000 pf PADDER	V7	6J4
C8	.0022mf	V8	6AQ5
C9	1mf	V9	6J4
C10	.1mf	V9	6J4
C11	25 pf	RFC1	2.5 μH - 4 SECTION
C12	200pf	RFC2	2.5 μH - 4 SECTION
C13	140pf AIR PADDER CONDENSER	RFC3	2.5 μH - 4 SECTION
C14	670pf	RFC4	40 TURNS ON 1 MEG. 2W RESISTOR
C15	1mf		
C16	.1mf		
C17	25 pf		
C18	200pf		
C19	140 pf A.P.C.		
C20	50 pf		
C21	.1mf		
C22	1mf		
C23	.01mf	XL	2,000 Kc. BLILEY-TYPE MO21
C24	100pf		
C25	140pf A.P.C.		
C26	200pf		
C27	140pf A.P.C.		
C28	25 pf		
C29	140pf		
C30	.01mf		
C31	.01mf		
C32	3pf		
C33	140 pf A.P.C.		
C34	.01mf		
C35	200pf		
C36	.01mf		
C37	.001mf		
C38	.001mf		
C39	50 pf A.P.C.		
C40	50 pf A.P.C.		
C41	500 pf (POST TYPE)		
C42	50 pf A.P.C.		
C43	500 pf (POST TYPE)		
C44	47 pf		
C45	.001mf		
C46	.001mf		
C47	25 pf A.P.C.		
C48	500 pf (POST TYPE)		
C49	25 pf A.P.C.		

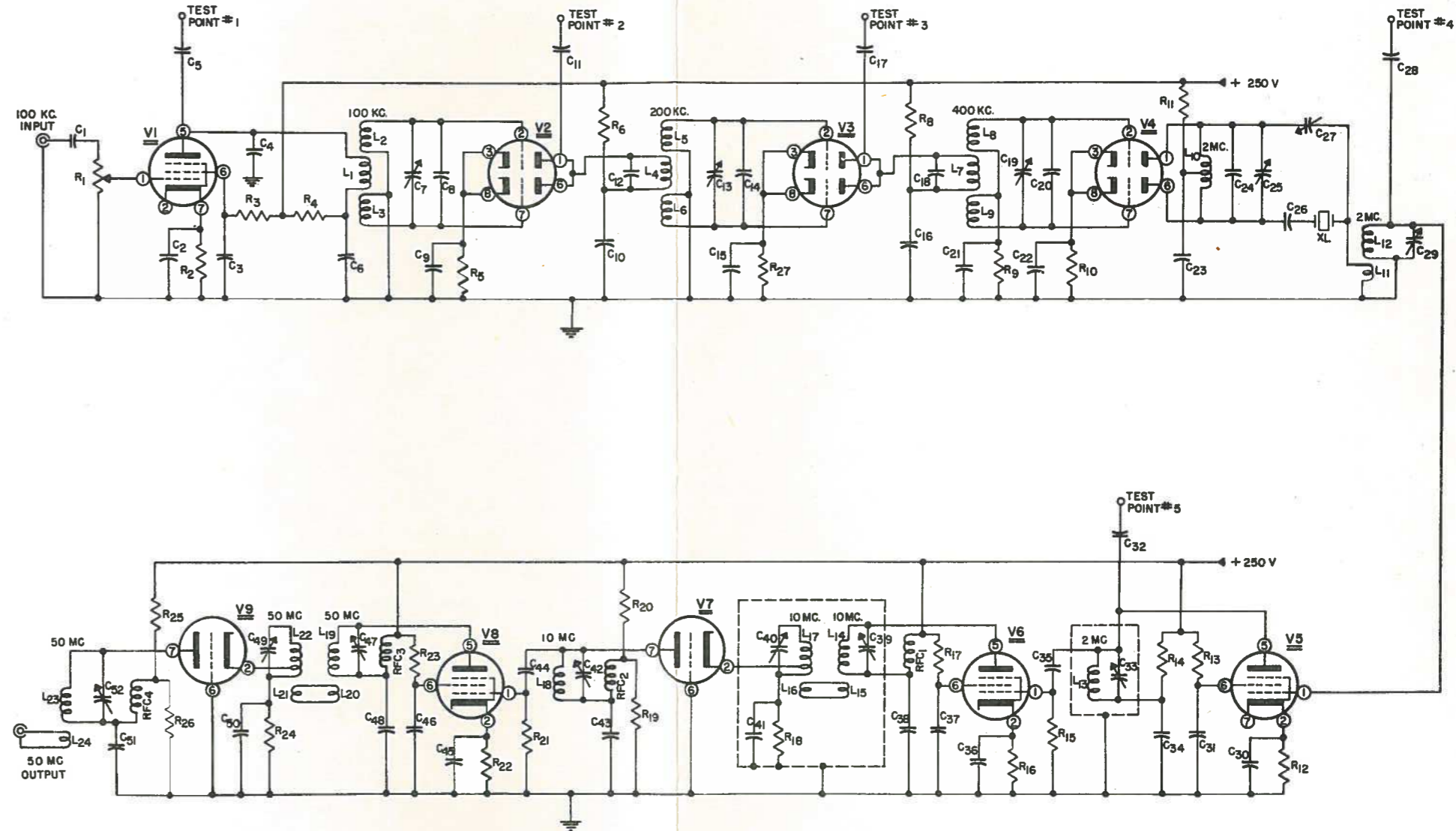


FIG. 1  
SCHEMATIC DIAGRAM OF FREQUENCY MULTIPLIER

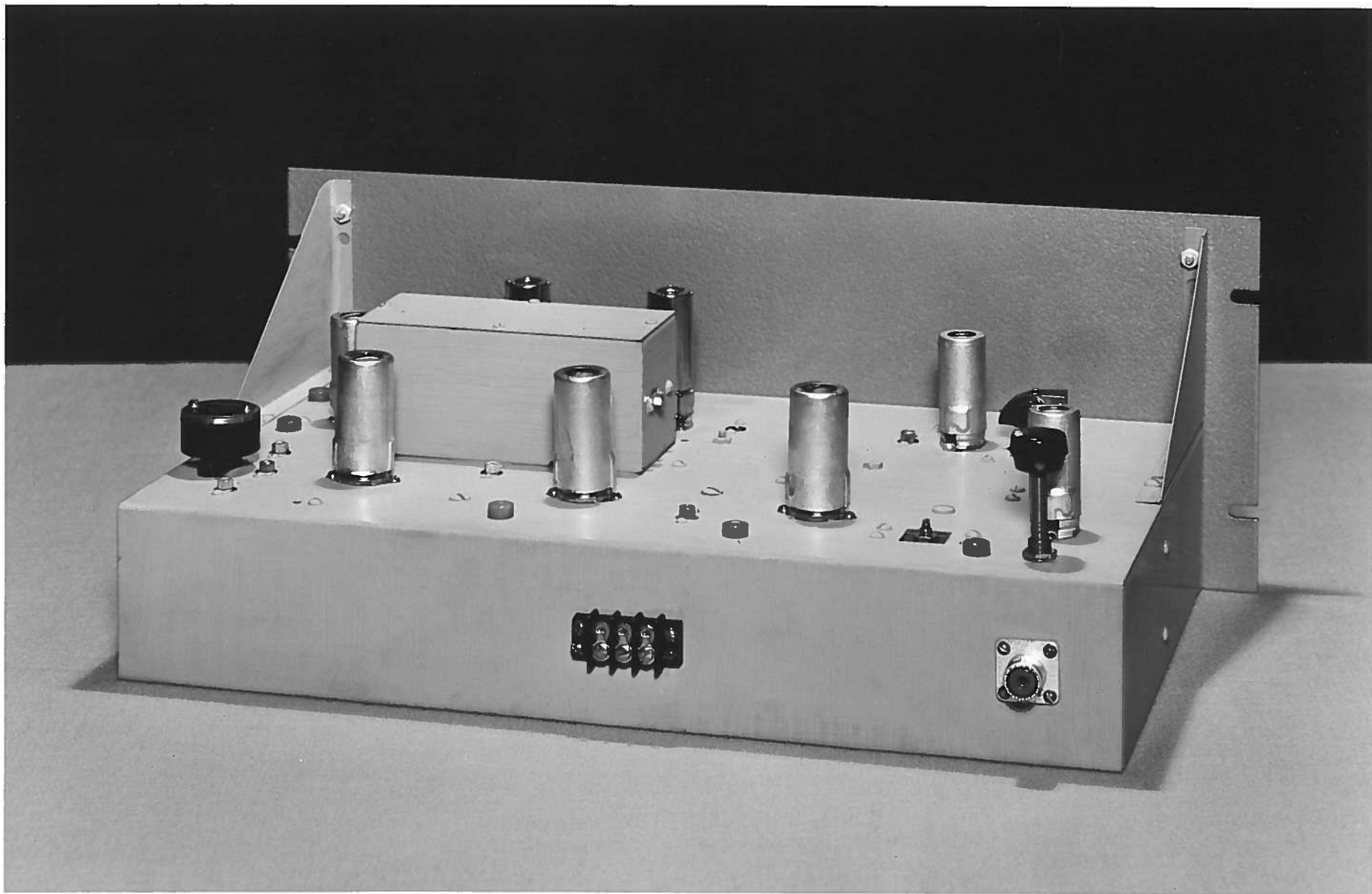


FIG. 2  
FREQUENCY MULTIPLIER  
TOP VIEW

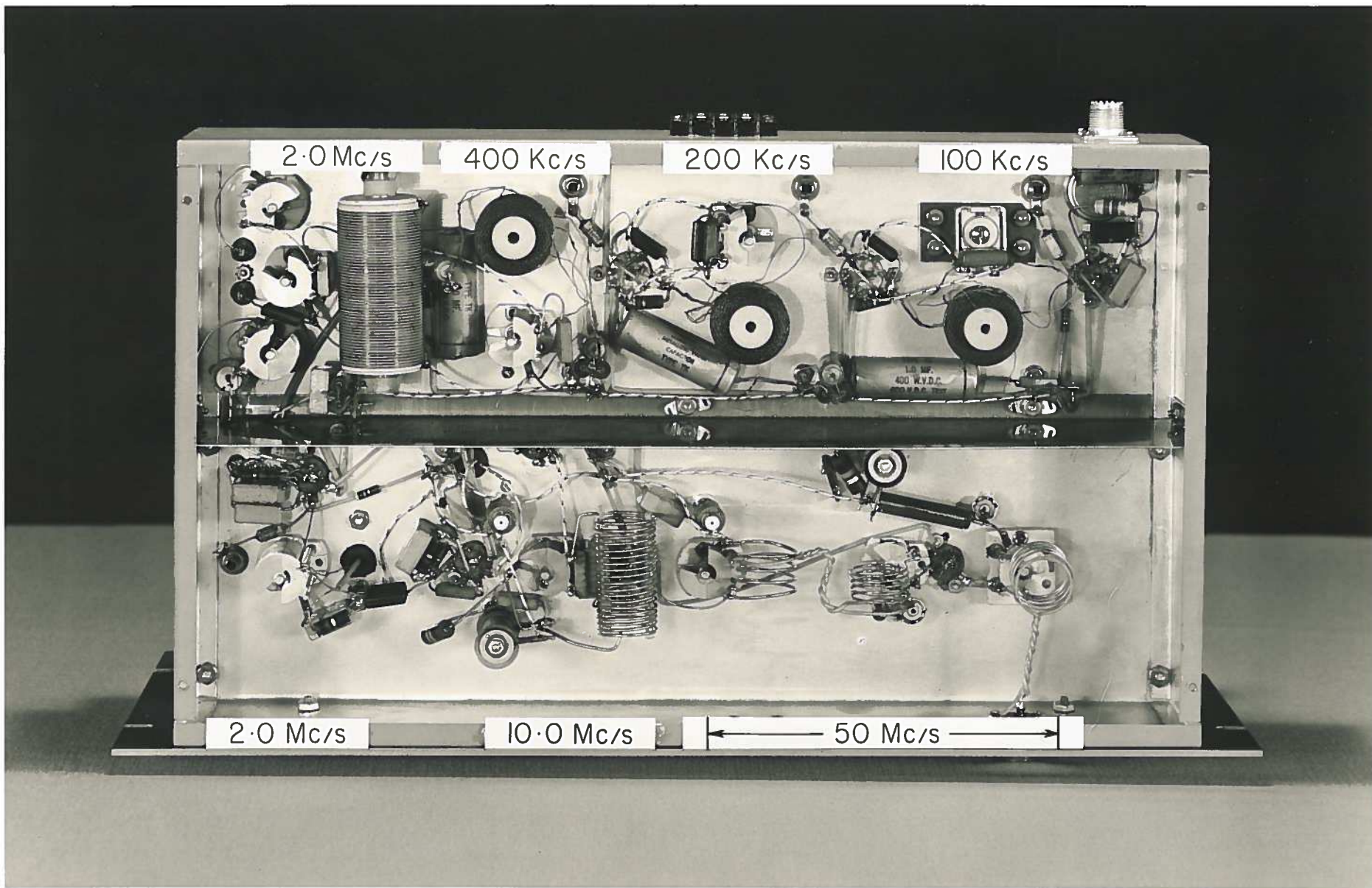


FIG. 3  
FREQUENCY MULTIPLIER  
INTERIOR VIEW