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REPORT NO. 29169-11

STUDY OF STEP RECOVERY DIODE FREQUENCY MULTIPLIER CHARACTERISTICS

RYAN

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STEP RECOVERY DIODE

FREQUENCY MULTIPLIER CHARACTERISTICS

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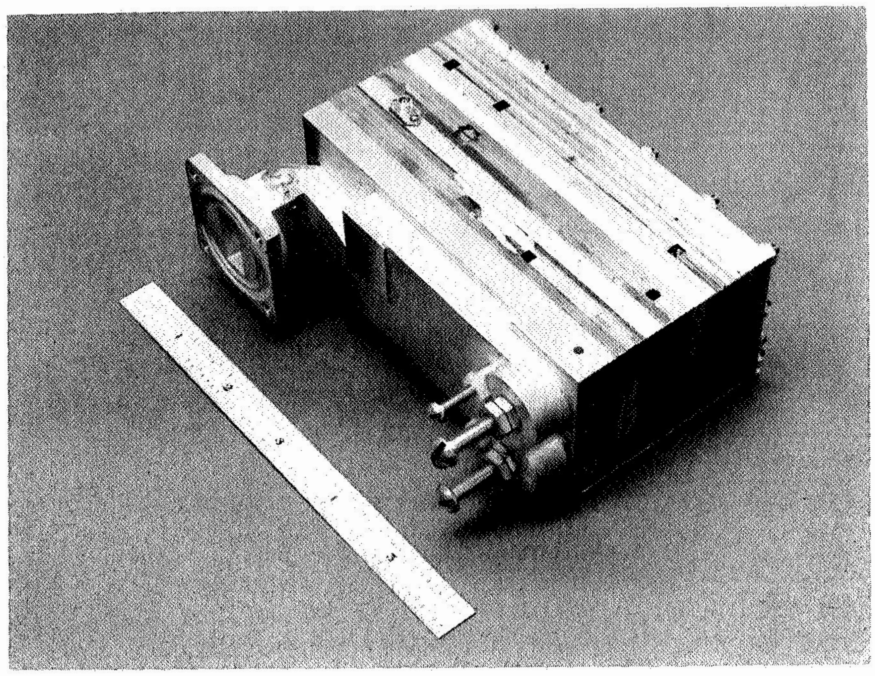
ABSTRACT

This report describes the design and tests of a compact solid-state, X-Band Transmitter (SSX) using step recovery diode (SRD) multipliers. Increased X-band output power is obtained by parallel connecting outputs of two multiplier stages. Limited environmental tests were performed and yielded promising results.



Solid State X-band Transmitter

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SECTION 1

INTRODUCTION

Ryan Electronic and Space Systems, a facility of the Ryan Aeronautical Company, is presently investigating the applications of Step Recovery Diodes (SRD's) in the microwave region. The program is supported by the Marshall Space Flight Center, Huntsville, Alabama, under contract NAS-8-20257. During this investigation, an experimental SRD multiplier operating at an output frequency in the X-band was constructed and given preliminary tests. These tests showed that the X-band output was very stable and contained less noise than the output from an X-band klystron. Power output of the multiplier was limited by the available diodes.

1.1 PROGRAM OBJECTIVE

The principal objective was to perform studies and experimental investigation in the design of solid state X-band transmitters employing step-recovery diode (SRD) multipliers.

1.2 RESULTS

A solid state transmitter was designed and built. Two approaches were investigated; the one selected uses two SRD multipliers.

The generator was tested for output power and noise under various environmental conditions.

This interim report describes the methods of construction and the results of the tests of the generator. The work described in this report is only a part of the overall development and implementation of the application of SRD's at Ryan. This work is a continuing effort and is being described in a regular series of progress reports.

The Solid State Generator was designed as a microwave generator for a zero i.f. frequency superheterodyne doppler radar operating at mid X-band.

This type of radar is sensitive to mechanically generated noise, generally known as "microphonism". The goal of the program was to design and construct a Solid State Microwave Source that would have minimum sensitivity to microphonism and would provide a 200 milliwatt output.

In designing such a generator, it became immediately apparent that a number of new packaging techniques would have to be developed. The packaging should be useable on all circuits involved, from the D.C. input to the microwave output, which meant printed circuits, stripline circuits and waveguides.

The design consideration led to the concept of stacked boards as shown in the frontispiece. The lamination of teflon boards and copper plates provided a homogeneous, well-damped assembly with good component density and excellent interstage shielding.

The design goal of minimal vibration sensitivity was met. The unit was exceptionally quiet during vibrations.

The electrical design goal of low noise was also met. The noise close to the carrier is almost as good as the best two-cavity klystron.

Ryan considers the generator a breakthrough in the development of solid state microwave sources.

SECTION 2

SYSTEM DESCRIPTION

2.1 ELECTRICAL OPERATION

The basic block diagram of the solid state generator is shown in Figure 1. A crystal controlled oscillator generates the fundamental frequency of 116.77 MHz. This frequency output is amplified by a buffer amplifier to drive an SRD multiplier which multiplies the frequency by nine to 1050.93 MHz.

The output from the times-nine (X9) multiplier is amplified and divided into two equal parts by a 3 dB hybrid divider. Each output in turn drives a times-ten (X10) SRD multiplier to produce the output frequency of 10.51 GHz. The power output from the X10 multipliers are combined in a waveguide hybrid to produce the X-band output signal.

The electrical and mechanical characteristics of the generator are listed in Table 1.

Figure 2 illustrates the original design of the SSX using a dual tripler stage and a low gain 5 dB L-band amplifier.

This approach was proposed because it required a gain of only 5 dB in the L-band amplifier, a gain readily obtainable in a single transistor. However, the circuit did require two tripler stages using transistors.

During the development it became clear that the packaging of the lumped constant tripler circuits would be bulky and, quite probably, microphonic. Consequently, a back-up program was started, using a single SRD times-nine multiplier in stripline configuration, followed by a 10 dB amplifier stage. This approach turned out to be much simpler than the former, and susequently, chosen for the generator, resulting in the block diagram of Figure 1.

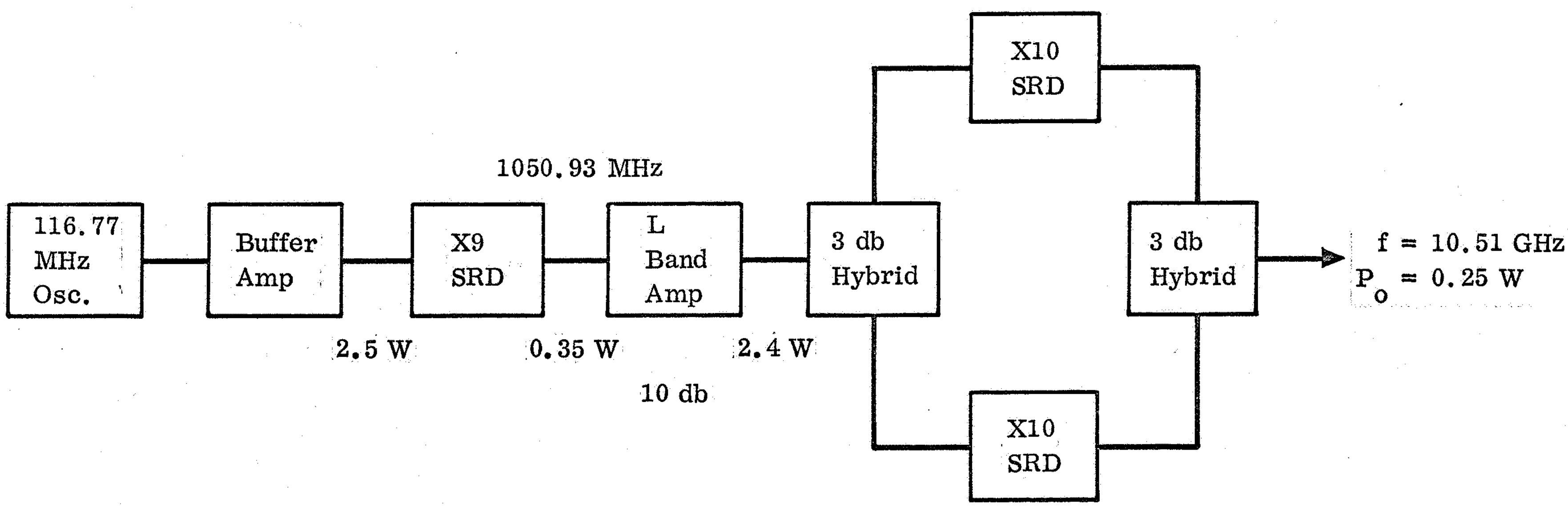


Figure 1 Solid State Transmitter Block Diagram

Table 1 Electrical and Mechanical Characteristics

Electrical:

Frequency:	10.5093 GHz
Input Power:	+25 vdc, 13 watts
Output Power:	250 mW
Efficiency:	1.8%

Mechanical:

Weight:	2.5 lbs.
Size:	4" x 5" x 2-1/4"

Environmental:

Temperature:	0°C to +70°C

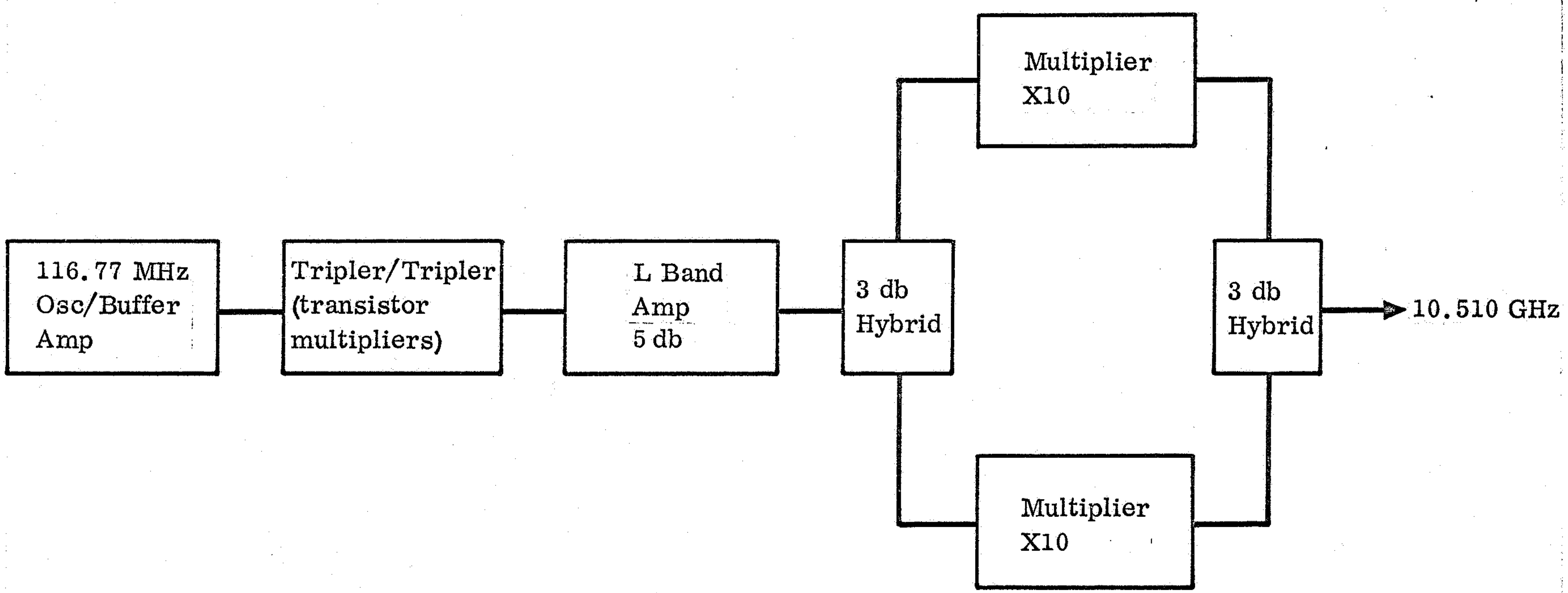


Figure 2 Transmitter Original Design Approach

The following describes the stages and discusses the design approaches.

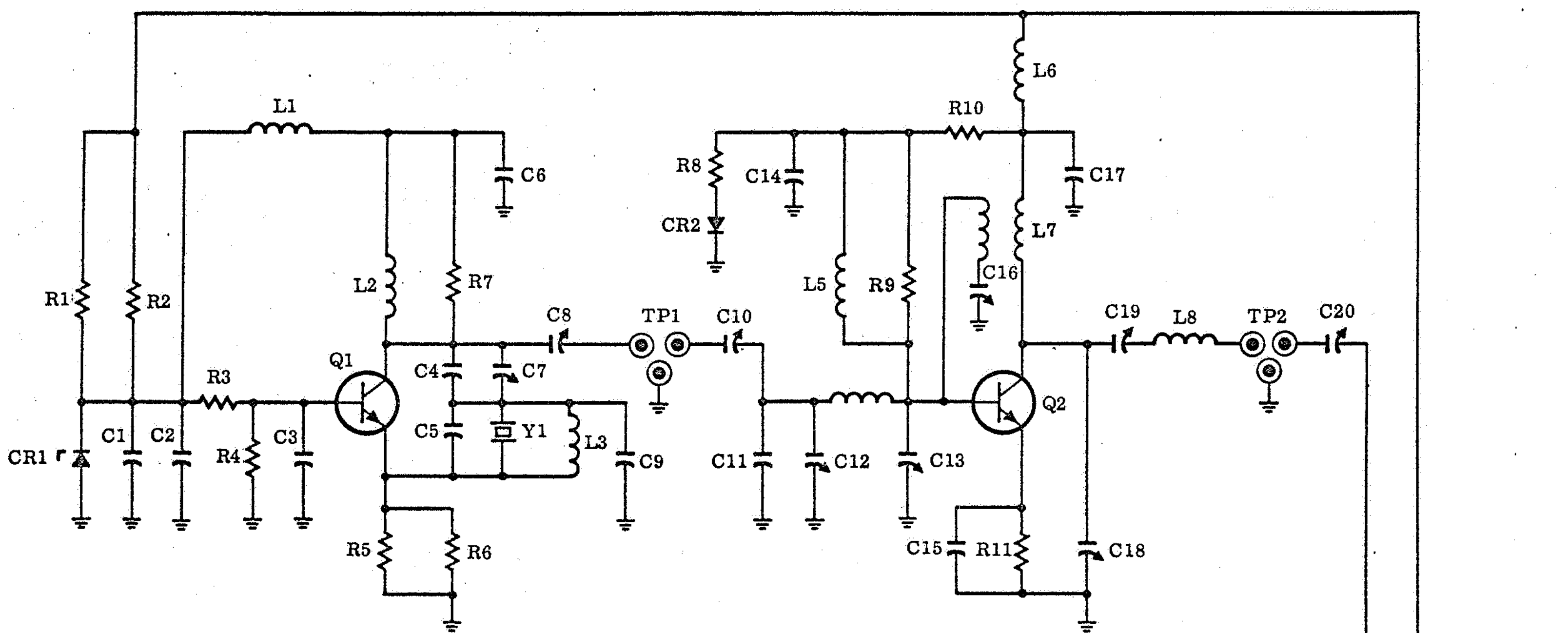
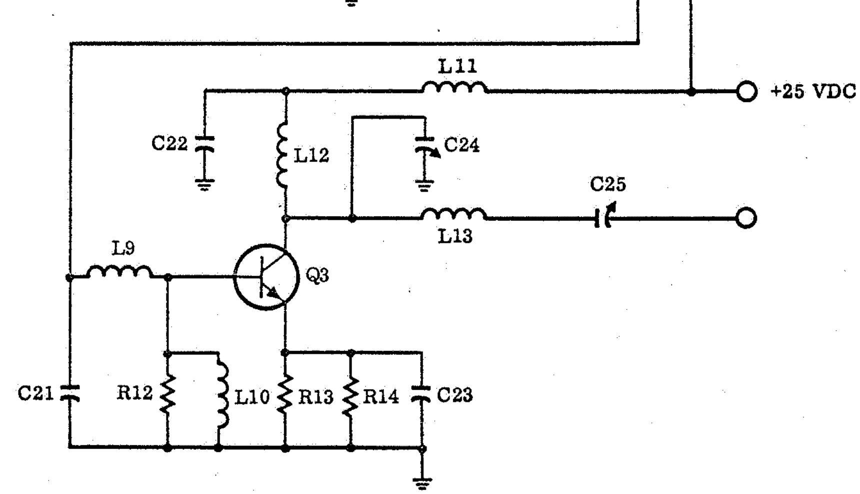
2.2 OSCILLATOR-BUFFER POWER AMPLIFIER

This circuit shown in Figure 3 contains three active transistor stages that generate a crystal controlled frequency of 116.77 MHz and amplifies it to a power level of 2.5 watts.

The construction shown in Figure 4 are of printed circuit design and are fabricated from fiberglass loaded teflon material. A spacer board with milled cut-outs is mounted directly over the components on the circuit board. The third board is a combined pressure plate and heat sink with clearance holes for the two large transistors, the crystal, the oscillator temperature compensating capacitor and two sets of test point terminals.

These test points prove to be very convenient in checking the unit after assembly. Three terminal posts comprise a test point set: ground post, output connection from the preceding stage and input connection to the following stage as shown in Figure 3. The input and output networks of all the stages are transformed to 50 ohms. The two signal posts are normally connected, but can be disconnected for hook-up to conventional test equipment with 50 ohm input impedance (power meters, test oscillators, spectrum analyzers, etc).

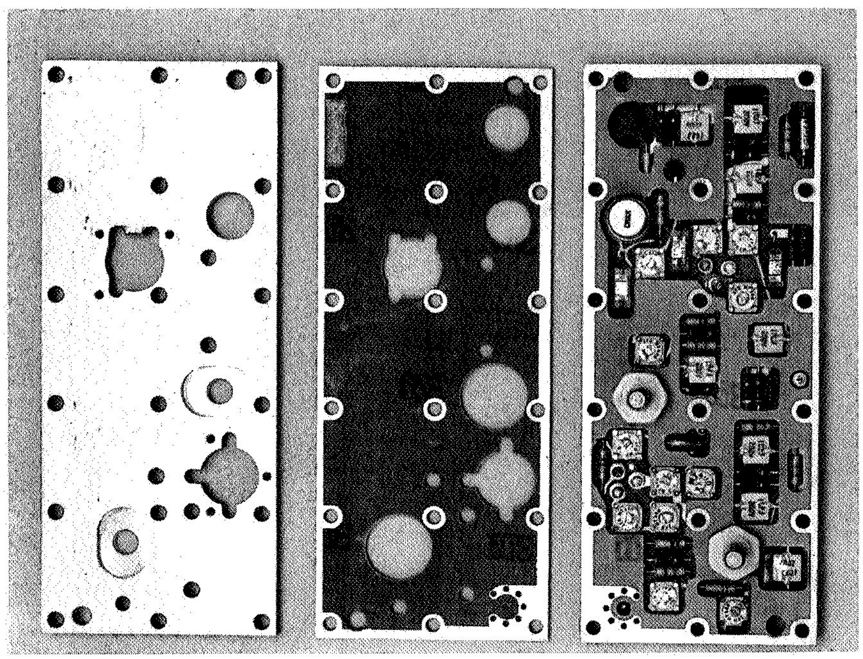
The oscillator is a Colpitts configuration utilizing a Fairchild FV-918 transistor. The stage operates on 12 VDC provided by a temperature compensated zener diode regulated supply line. The base of the transistor is bypassed to ground with a capacitor, C3. The oscillator tank inductor, L2, is shunted by a resistor, R7, to reduce the Q. The oscillator is matched with an L network to 50 ohms.

C1	- 1µF		C14, C15, C17	} 1000 pF	
C2, C3, C6	- .001µF		C22, C23		
C4	- 10 pF				
C5	- 4.7pF		Q1 - FV918 FAIRCHILD		
C7, C8, C12	} 4.0 - 15 pF		Q2, Q3 - TA7146 RCA		
C10, C13, C16					
C18, C19, C20			CR1 - IN943		
C21			CR2 - IN914		
C9	- 56 pF				
C11	- 12 pF				

R1, R2	- 2.7KΩ	L1	- 3.3 µH
R3, R10	- 6.8KΩ	L2, L4	} .1 µH
R4	- 4.7KΩ	L7, L9	
R5, R6	- 2.0KΩ	L12	
R7	- 12.0 KΩ	L3	- 3.9 µH
R8	- 100Ω	L5, L6	} 1.8 µH
R9, R12	- 470Ω	L10, L11	
R11	- 47Ω	L8, L13	- .33 µH
R12, R14	- 12Ω	Y1	- 116.77 CRYSTAL

Figure 3 Oscillator/Buffer Amplifier



a b c

Figure 4 Mechanical Layout, Oscillator-Buffer Power Amplifier

The crystal is a series resonance unit mounted in a TO-5 transistor can. The stray capacity across the crystal is resonated with an inductor, L3. A temperature compensating capacitor, C5, connected across the crystal provides a temperature tracking correction of approximately 10%. The oscillator delivers 10 milliwatts.

The buffer amplifier uses an RCA 2N5090 transistor in a neutralized common emitter configuration. The gain of this stage is 14 dB. This yields a power output of 260 milliwatts when driven by the 10 milliwatts from the oscillator. Neutralization provides approximately 35 to 40 dB reverse attenuation. A diode, CR2, is used in the bias circuit to compensate for temperature variation of the emitter-base junction. The input matching circuit utilizes a T network. The output matching circuit uses an L network. Through use of the test points neutralization is straightforward and simple. This neutralized buffer stage reduces output load variations effect on the oscillator.

The power amplifier stage also uses an RCA 2N5090 transistor in a common emitter unneutralized configuration. The input matching circuit is a T network and the output matching circuit is an L network. This stage provides 10 dB power gain which delivers 2.5 watts at 116.77 MHz into a 50 ohm load. Total current for the board is approximately 0.12 A, at +25 VDC.

2.3 MULTIPLIER X9

The oscillator buffer amplifier provides an output of 2 watts at 116.77 MHz to drive the X9 multiplier. This step recovery diode multiplier generates the ninth harmonic at 1050.93 MHz. The power efficiency of the multiplier is 17.5% which yields an output of 350 milliwatts.

A circuit diagram of the X9 multiplier is shown in Figure 5. The step recovery diode is an HPA 0320, which was selected on the basis of required power output, input and output frequencies, and the diode's reverse bias capacitance.

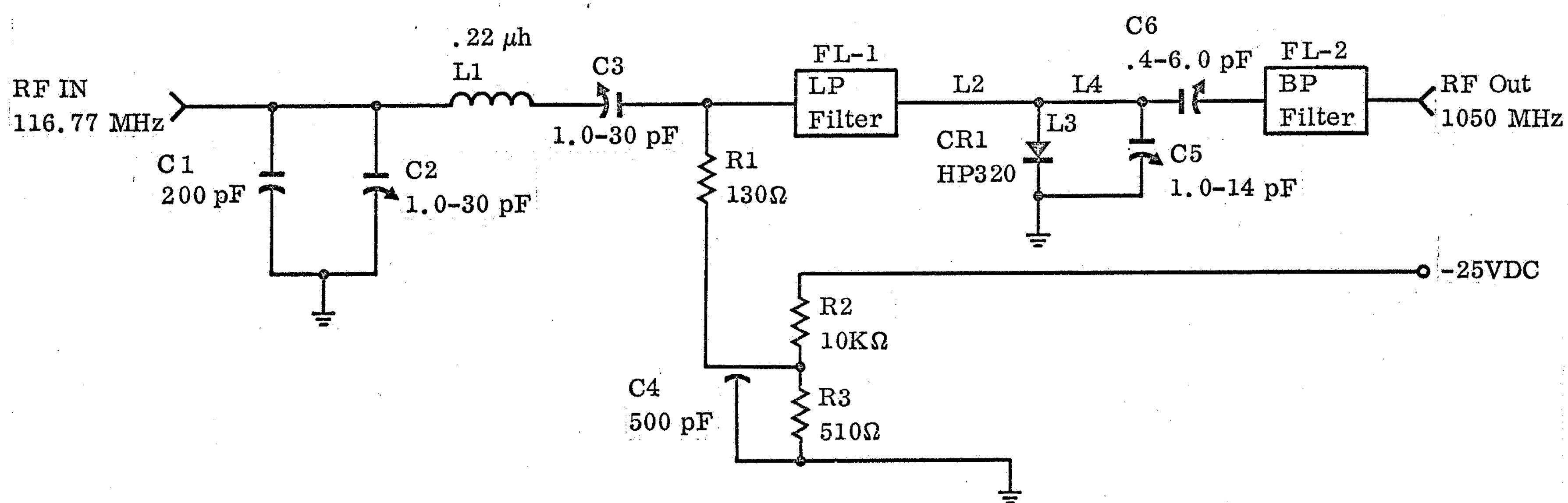


Figure 5 X9 SRD Multiplier

The multiplier is a shunt circuit using lumped circuit elements at the input frequency and stripline circuit elements at the output frequency. A combination of self and fixed bias for proper operation of the SRD is supplied by the bias network consisting of R1, R2, R3, and C4. A transmission line choke (FL-1) prevents the ninth harmonic from flowing back into the input circuit. Components L2, L3, L4 are stripline inductances resonated by C5 and C6 to optimize the power efficiency.

The input impedance is matched fo fifty ohms by C1, C2, C3 and L1. An interdigital bandpass filter (FL-2) in the output suppresses all harmonics except the desired ninth harmonic. The mechanical layout is shown in Figure 6.

The eight stripline printed circuit boards comprising the X9 SRD Multiplier are shown in Figure 6. Most of the multiplier circuit is illustrated in Figure 6d. The two wide strips in the center comprise the input choke, FL-1. The ground planes of this choke are the wide area centrally located in Figures 6c and 6g. The interdigital filter is formed by the parallel lines in Figure 6a. Figures 6b, 6e, and 6f are dielectric spacers used to provide spaces between the major circuit boards. Slots are milled in the dielectric to accept piston-type adjustable capacitors with access allowed for adjustment through slots to the board edges.

2.4 L-BAND AMPLIFIER

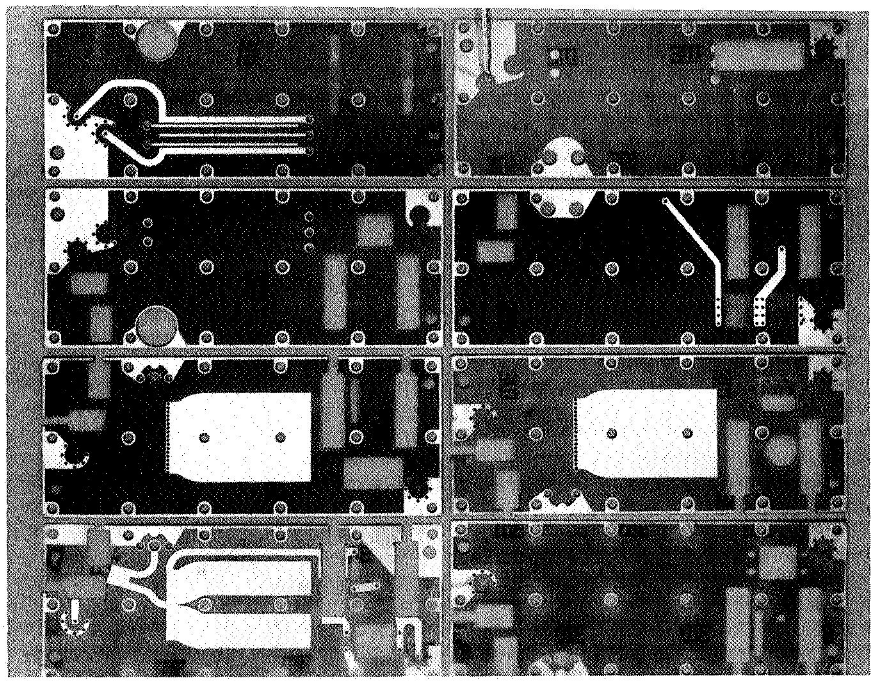
The L-band amplifier shown in Figure 7 receives the 350 milliwatt 1050.93 MHz signal from the X9 multiplier and amplifies it to approximately 2.4 watts required to drive the X10 multiplier. The amplifier consists of two common emitter Class C stages, a 2N4430 driver and a 2N4431 power amplifier. All matching networks are stripline distributed circuits. Johannson variable capacitors are utilized for circuit tuning.

a

b

c

d



e

f

g

h

Figure 6 Mechanical Layout, X9 Multiplier

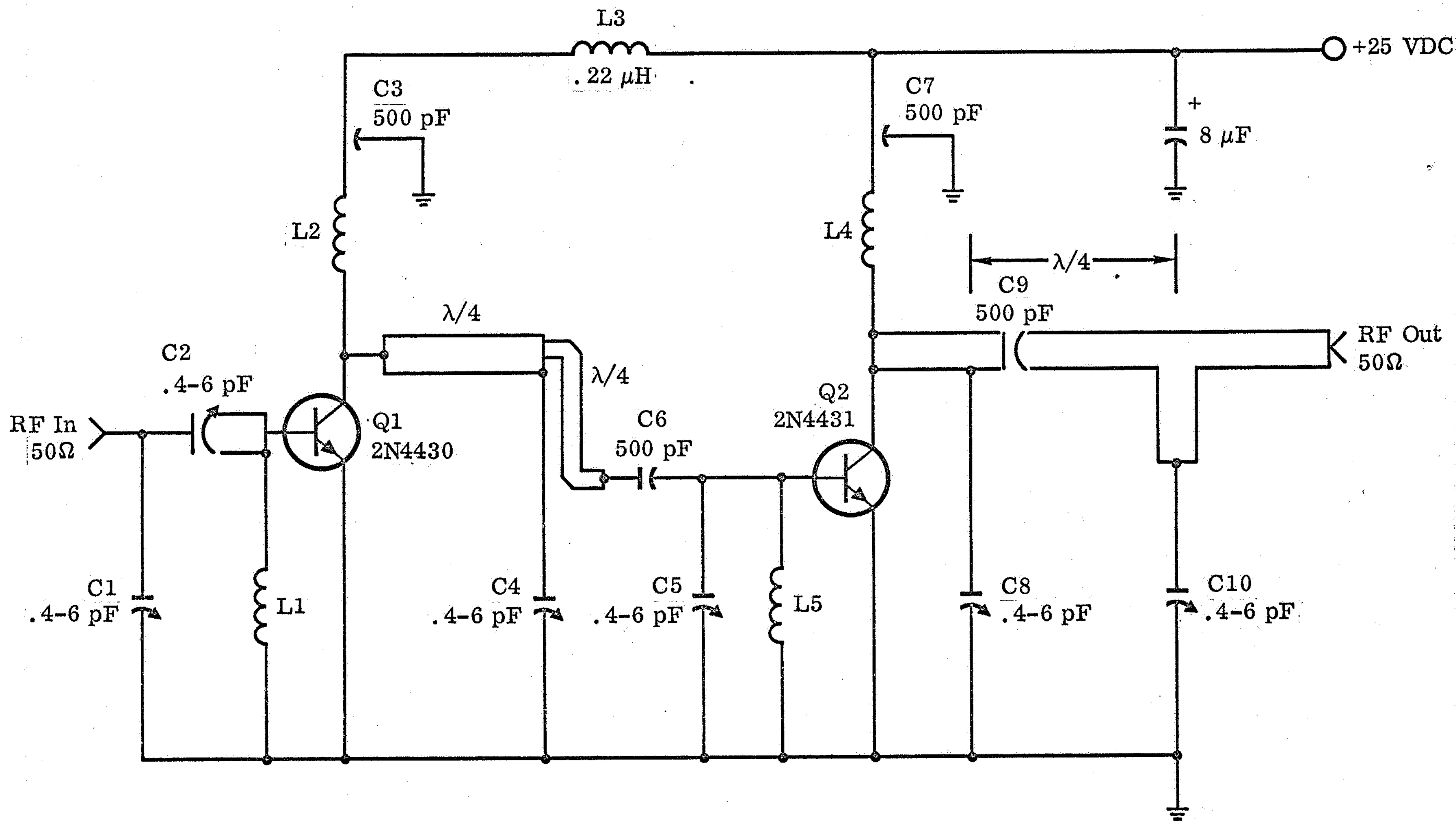


Figure 7 L-Band Amplifier Schematic

Components L1, L2, L3, L4 and L5 are RF chokes. C1 and C2 are used to resonate the input to Q1 which is a shortened quarter-wave section. A two-section quarter-wave transformer is used to step up the collector impedance of Q1 from 10 to 150 ohms to the input of Q2 which is resonated by C5.

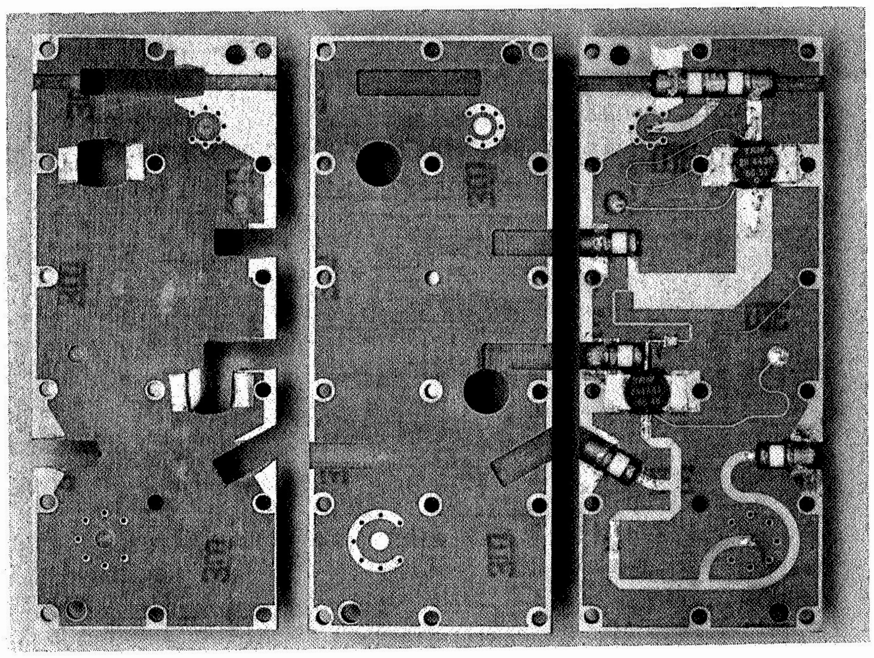
The capacitive reactance of C4 is presented as an inductive reactance to the collector of Q1 through a quarter-wave transformer. The collector of Q2 is tuned by the equivalent of a double-stub tuner. C8 is a capacitive shunt and the combination of C10 and a length of line slightly greater than $\lambda/4$ is an inductive shunt; C9 is a DC block only.

The L-band amplifier consists of three printed boards shown in Figure 8. All of the stripline circuits are printed on the board shown in Figure 8. The input from the X9 multiplier filter enters at the top left of 8C through the connector surrounded by the circle of small holes. This passes through the variable capacitor at the top of the base of the 2N4430. The thin looped line is the choke L1 to ground. The output of the stage passes through the wide (low impedance) line to the shunt capacitor and a thin (high impedance) line to the base of the 2N4431. The output of this stage passes through two sections with shunt "T" arms to the output connector in the lower right of the boards. The thin wavy lines are chokes.

The board shown in Figure 8 is the cover board for the L-band amplifier while 8B is a spacer board.

2.5 MULTIPLIER X10

The X10 SRD multiplier is driven with 2.4 watts at 1050.93 MHz from the L-band amplifier and delivers an output of 250 milliwatts at 10.5093 GHz. Two separate identical multipliers are operated in parallel to double the power output. A 3 dB hybrid is used in the input to divide the drive power equally for each multiplier. The outputs of the multiplier are combined in a 3 dB hybrid.



a b c

Figure 8 Mechanical Layout, L-band Amplifier

The input circuit shown in Figure 9 consists of a stripline hybrid power divider. The combination of C3 and C4 in one arm and C5 and C6 in the other arm, each with a shortened $\lambda/4$ transmission line serve to transform to a suitable impedance for the multiplier diodes CR1 and CR2. Capacitors C8 and C9 are tuning capacitors at the input frequency and serve as radial chokes at the input frequency.

The step recovery diodes, CR1 and CR2 are coupled to resonant X-band cavities milled in an aluminum block. The SRD's are biased to the correct operating point by a zener diode and an appropriate voltage divider.

Output from each multiplier resonant cavity is coupled to separate arms of an X-band side-wall coupler connected as a 3 dB hybrid. This coupler combines the output of both multipliers into a single X-band waveguide output connector.

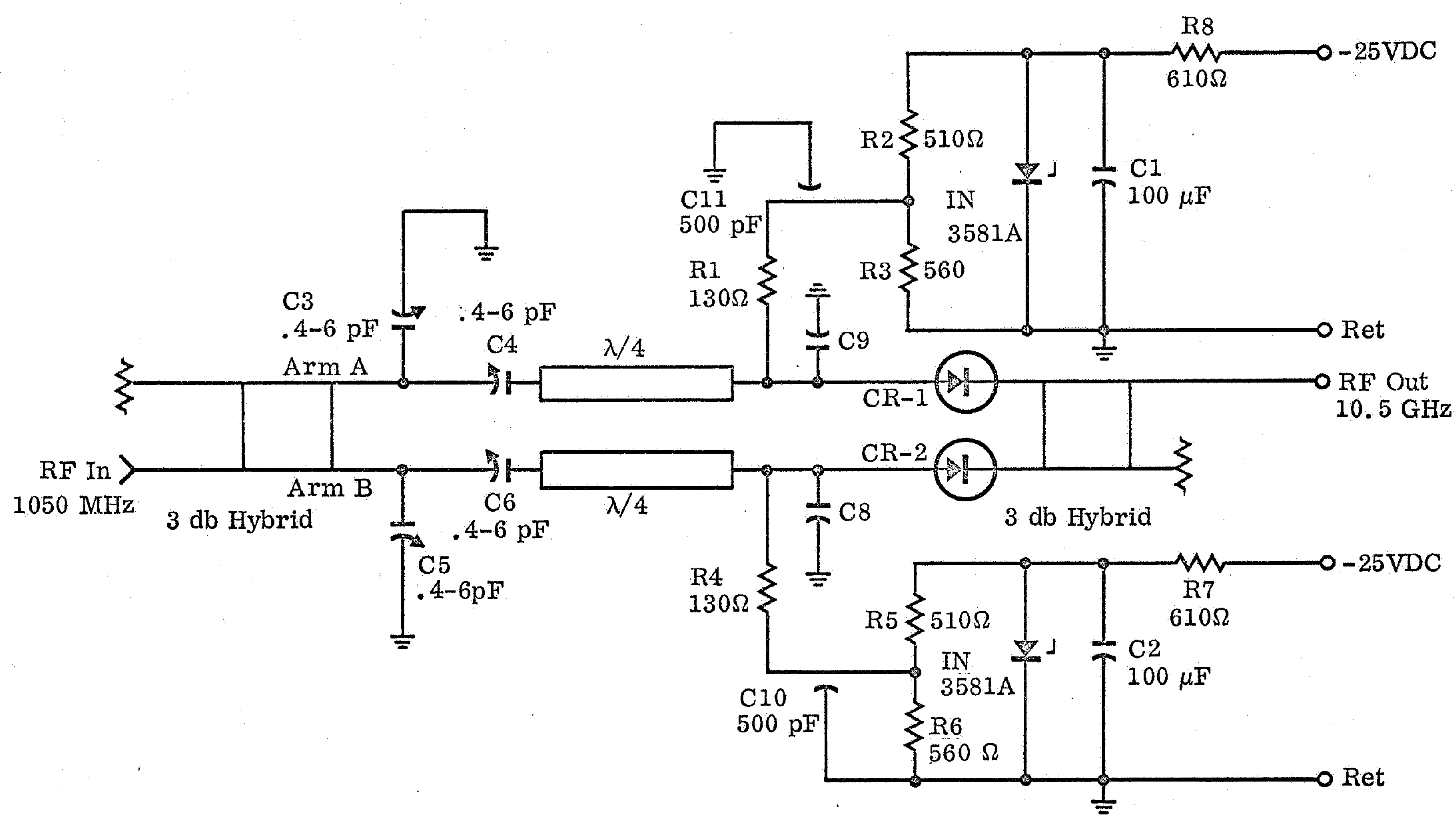


Figure 9 X10 SRD Multiplier, Schematic (L to X Band)

SECTION 3

TEST RESULTS

The solid state generator was tested for noise, vibration and temperature. The testing is described below.

3.1 NOISE MEASUREMENTS

The purpose of this test was to measure the noise between 1 kHz and 100 kHz from the carrier.

The test setup is shown in Figure 10. The noise of the generator is compared to that of a klystron (VA514) and of a calibrated noise source. The test setup is an existing balanced bridge, but is shown here unbalanced for simplicity.

The output is recorded for spectral analysis as shown in Figures 11 and 12. By comparison it is evident how low the noise output of the SRD generator is. It approximates that of a good two-cavity klystron. A bandwidth of 100 Hz was used for the recordings. With a noise lamp noise figure of 12.1 dB (reference) and a mixer conversion loss of 10.5 dB; the available noise from the noise source was -131.4 dBm.

The noise output is 100 Hz bandwidth at the different widths from the carrier and the corresponding noise power level below the carrier are listed below:

	100 kHz	50 kHz	10 kHz	1 kHz
Noise power below carrier	-132 dB	-127 dB	-129 dB	-124 dB

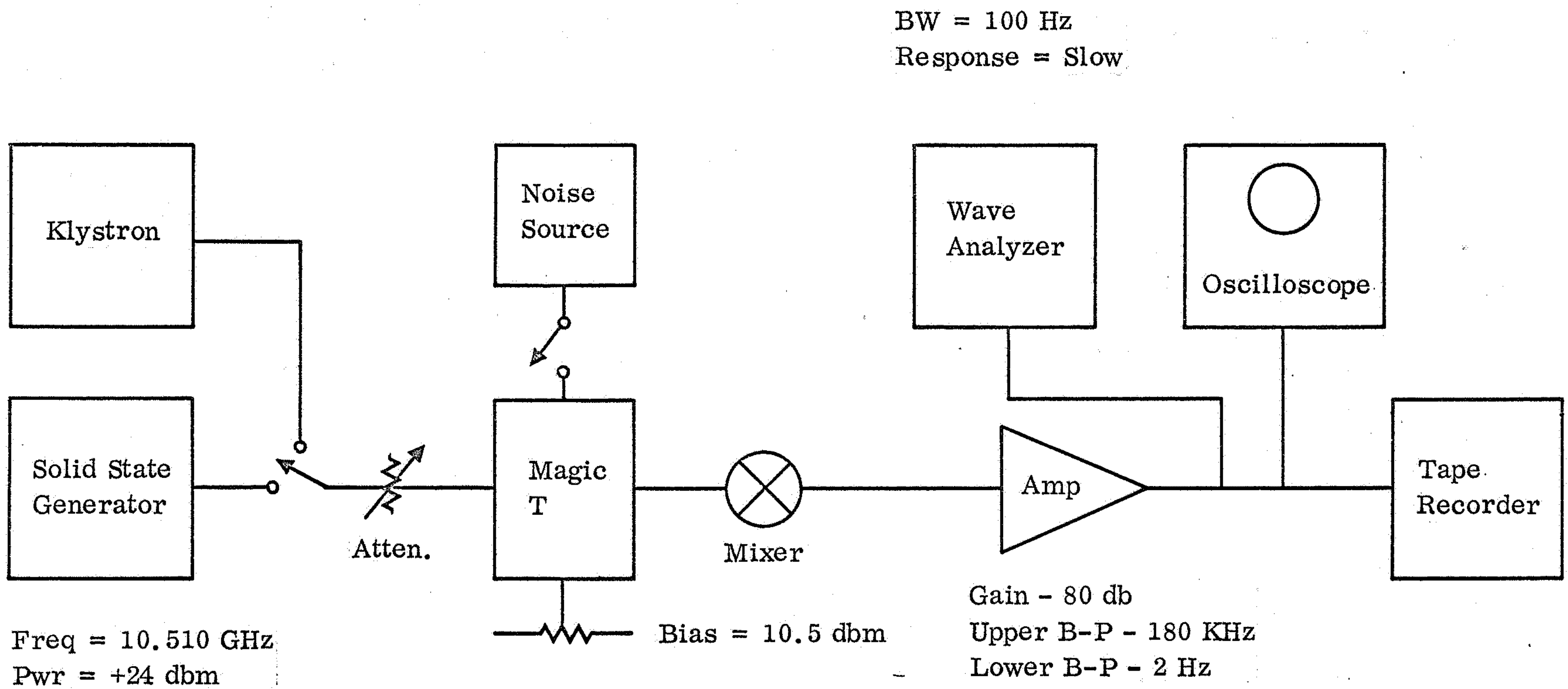


Figure 10 Noise Test Setup

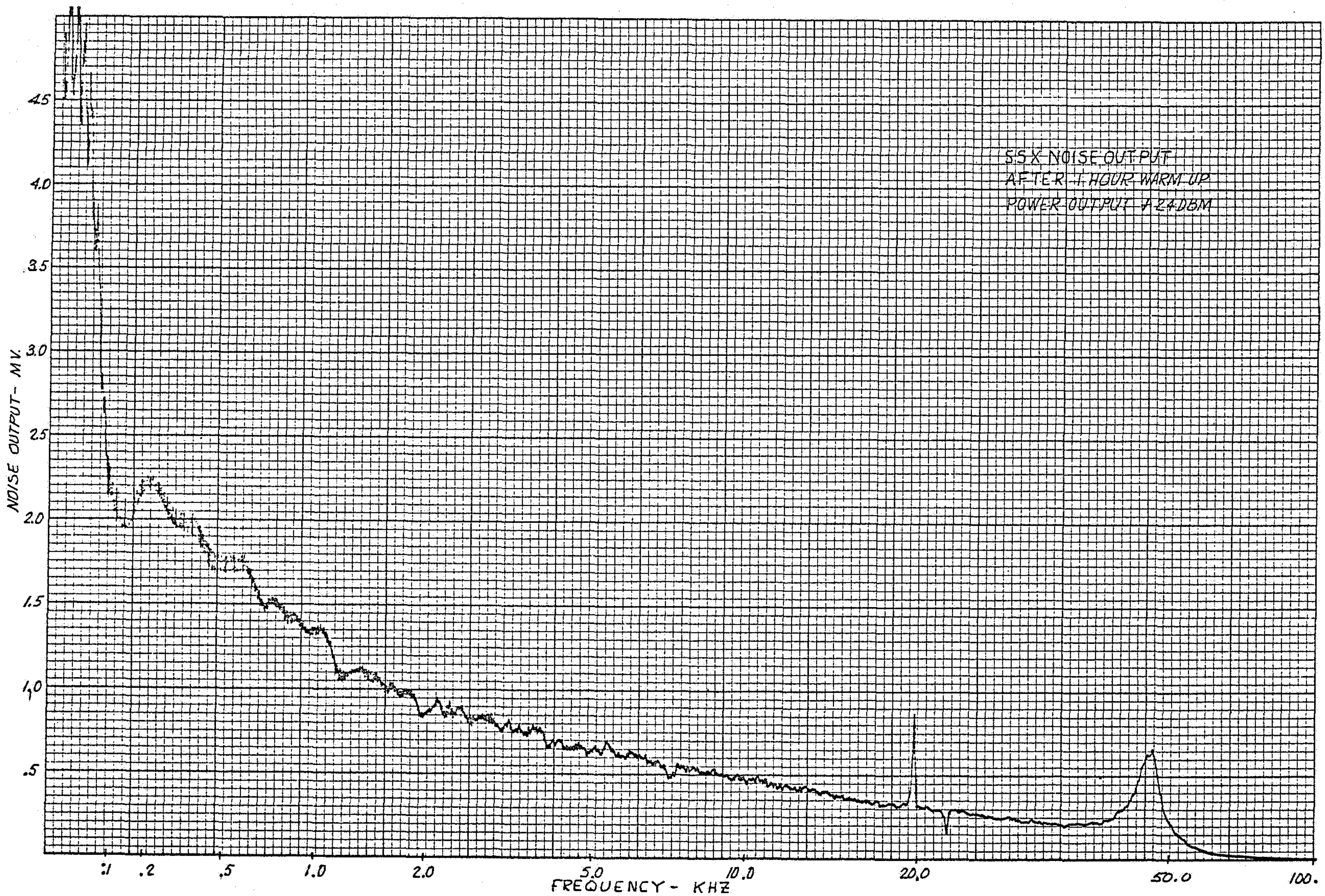


Figure 11 SSX Noise Output After One Hour Warmup; Power Output +24 dBm

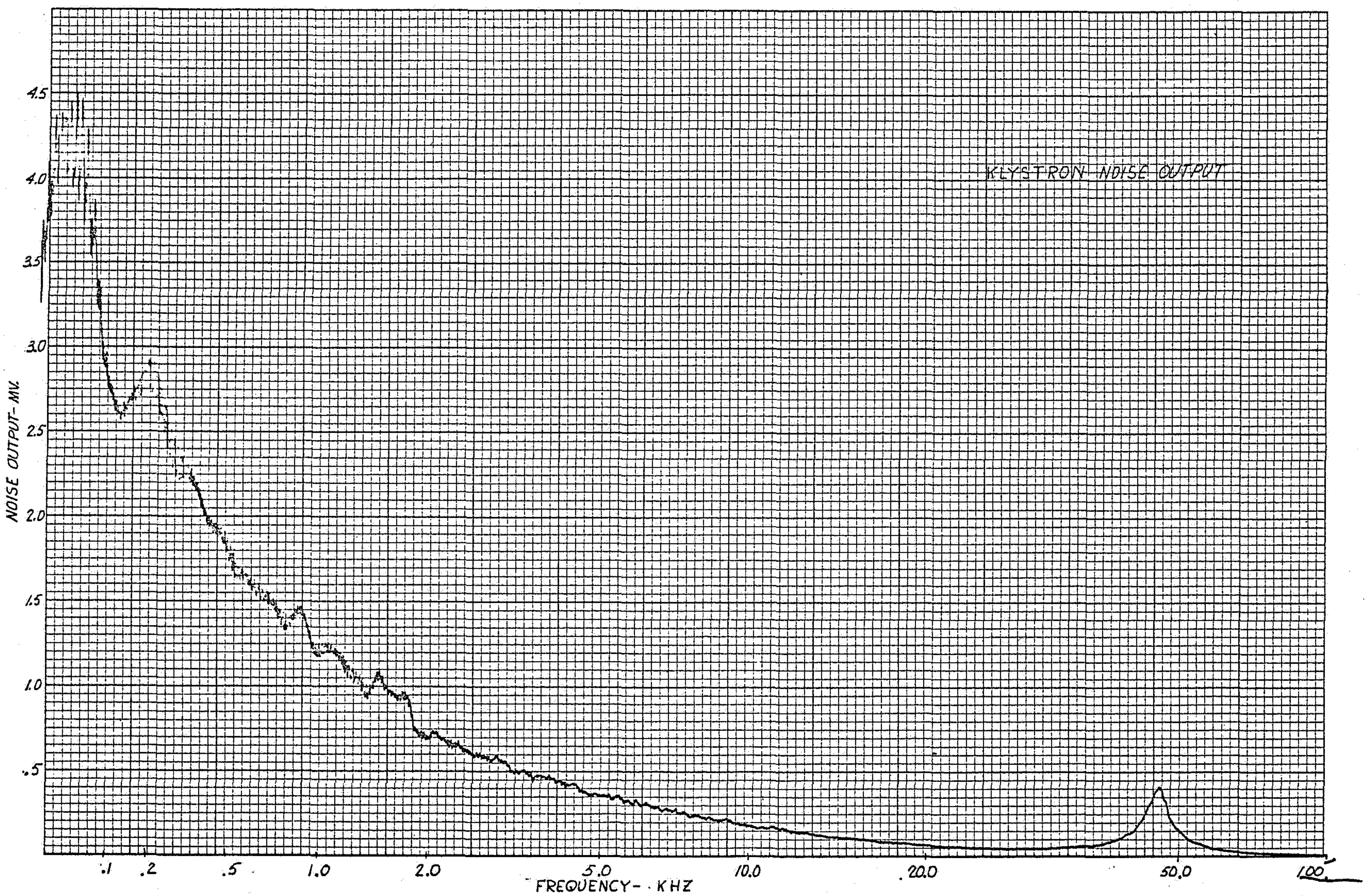


Figure 12 Klystron Noise Output

3.1.1 Noise at 1 kHz

$$P_{Bc} = -124.5 \text{ dB below carrier}$$

The output from the 80 dB gain amplifier was observed on an oscilloscope.

Noise was observed on the oscilloscope in the form of spikes that varied in width, amplitude and duration. Because of the popping sound this noise makes, in a headset, this noise is called "Firecracker Noise" or Random Bursts.

3.1.2 Results and Conclusions

Examination of the test results proved that after DC power was applied to the unit and while the unit was changing temperature, due to its own heat dissipation, the noise output was high. After approximately one hour the noise output from the unit decreased to an acceptable level. Figure 13 shows the noise immediately after turn-on.

It is felt that the cause for this type of noise, see insert above, was wear on the adjustable Johannson capacitors and the temperature instability of the teflon rotor lock. The threaded portion of the rotor and the stator of the capacitor are made of brass and then gold-flashed.

After the capacitors are cycled in and out a few times, deterioration of the threads results and the gold-flashing flakes off inside the capacitors. Because these capacitors are in high intensity fields, migration or floating of the gold particles results inside the capacitors. This was observed in the output as random noise bursts.

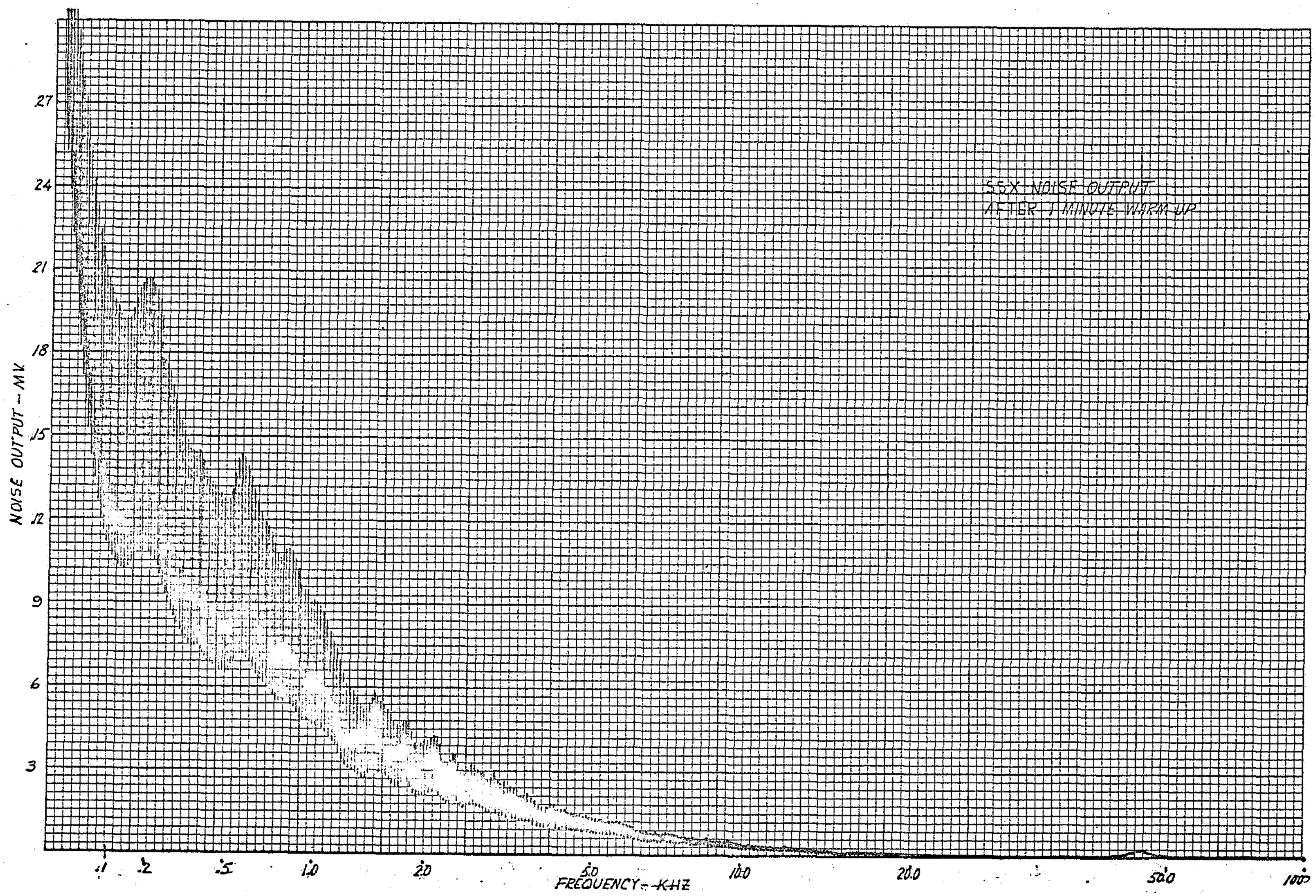


Figure 13 SSX Noise Output After One Minute Warmup

3.2 ENVIRONMENTAL TESTS

3.2.1 Purpose

The purpose of these tests was to examine the low frequency vibrational characteristics and the temperature characteristics of the solid state generator.

3.2.2 Test Procedure Vibrations

The generator was mounted on the vibration exciter for vibration in the vertical axis (see Figure 14). A vibration damped flex-waveguide connected the RF output to a crystal diode detector. An oscilloscope was used to monitor the random noise bursts. A tape recorder was connected to the output of an 80 dB amplifier to record the output during vibration runs. The recorded signal was next run through a frequency analyzer to generate the spectrum shown in Figure 15. The curves show the output noise for:

- Nonvibrating, Power Output +24 dBm, Figure 15, Curve C
- Vibrating at $.004G^2$/cps, Power Output +24 dBm, Figure 15, Curve B
- Vibrating at $.006G^2$/cps, Power Output +24 dBm, Figure 15, Curve A

The drive signal was white noise with a 20 Hz to 20 kHz bandwidth.

3.2.3 Results and Conclusions

The spectral plots (Figure 14) show that there are signal outputs at some specified frequencies below 5 kHz.

This indicates that some parts of the unit are mechanically resonating at each specific frequency. Because of the excellent mechanical properties of the sandwiched stripline board assembly, it is felt that the noise is caused by one or a combination of the following:

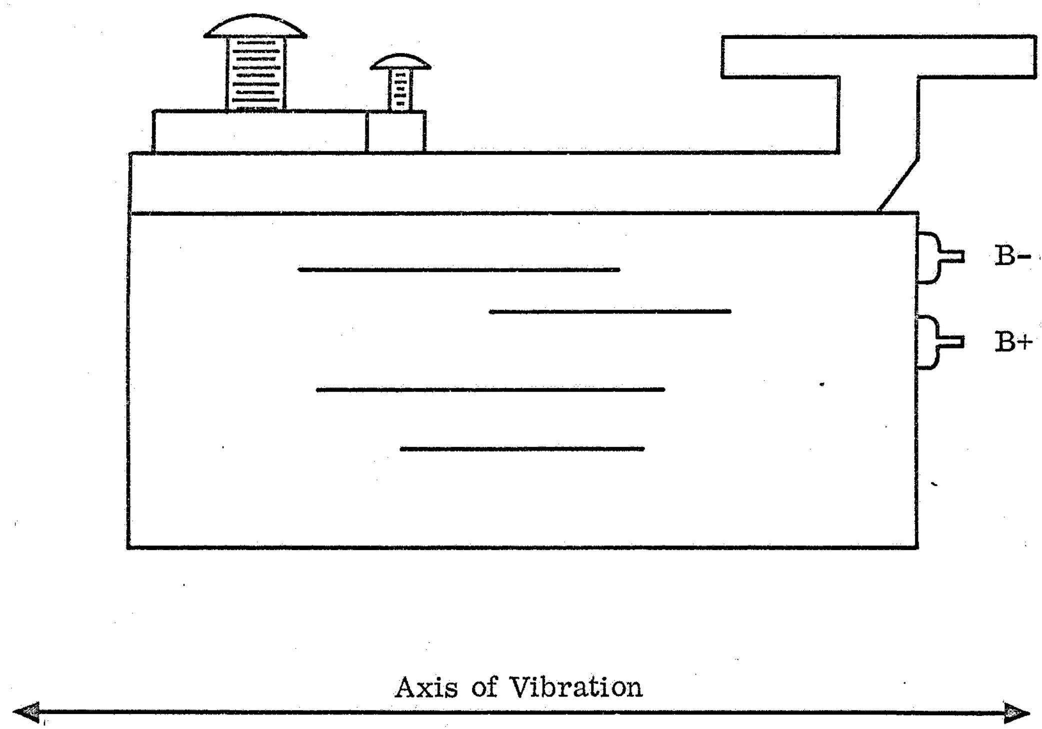


Figure 14 Solid State Generator, Vibration Test

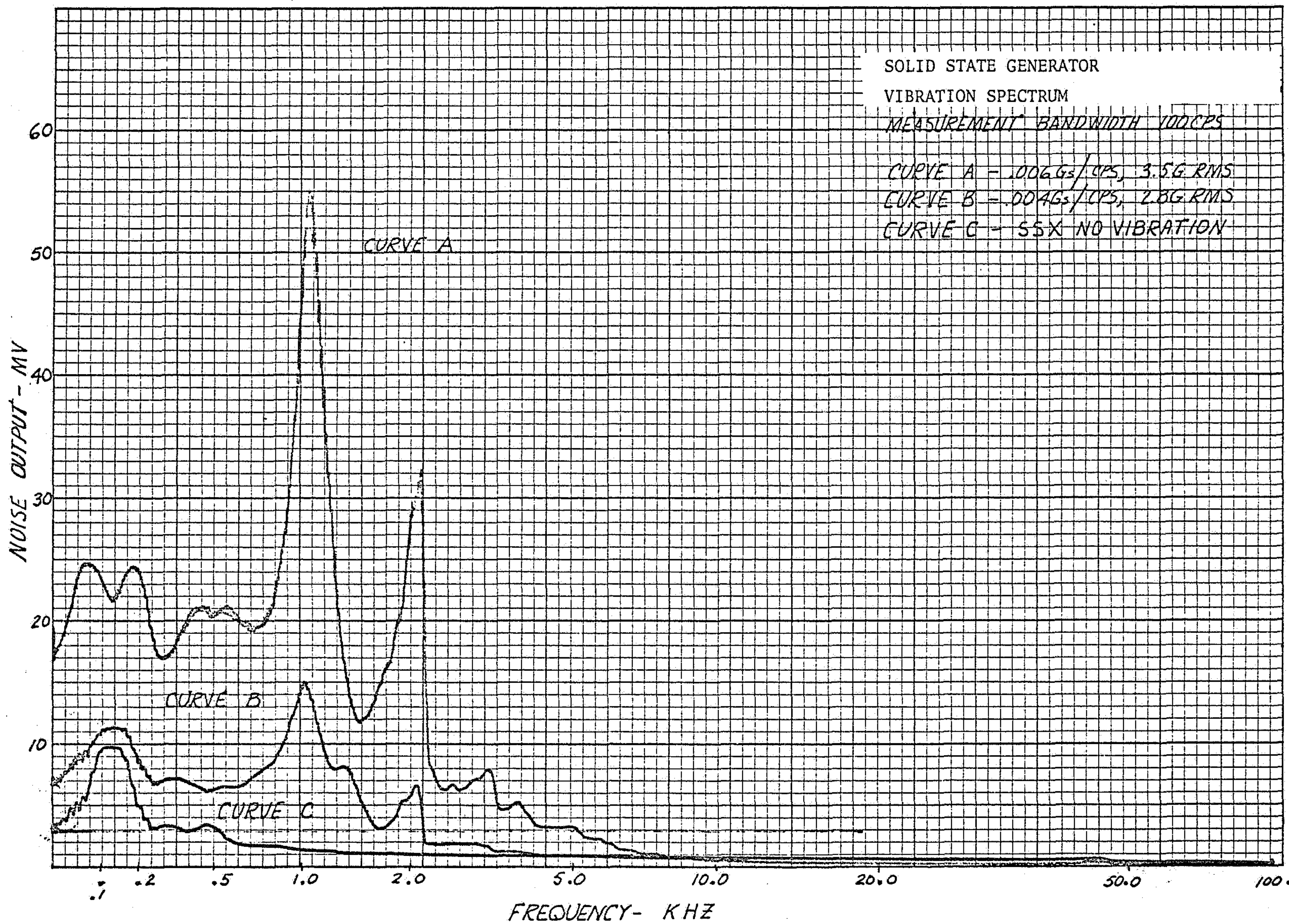


Figure 15 Solid State Generator Vibration Spectrum

a. Mechanical vibration transmitted to the Johannson capacitors.

b. Mechanical vibration transmitted to the walls of the waveguide hybrid.

c. Mechanical vibration transmitted to the flexible waveguide.

It was not possible to identify the noise peaks with the possible main sources. However, the first two causes can readily be eliminated in later units. The last source can be identified by use of various lengths and types of waveguide. Funding limits did not allow further investigation.

3.3 TEMPERATURE TESTS

3.3.1 Test Procedure

The solid state generator was placed in an oven with a waveguide connecting the output to a crystal diode detector. An oscilloscope was used to monitor the random noise bursts. In addition, frequency and a power were measured. An oscilloscope and a wave analyzer were connected to the output of the 80 dB amplifier to observe the noise output during the temperature run.

3.3.2 Results and Conclusions

The results of power output versus temperature are shown in Figure 16, while frequency variations and noise bursts are linked in Table 2. This data indicates that the frequency stability was excellent and the random noise bursts and rms noise were low at each specified stabilized temperature.

Further examination of Table 2 shows that the +28 vdc input current changed over the temperature range. It is felt that this is caused by changes in the impedance match in the input and output circuits of the L-band amplifier. The changes in the matching circuits resulted in changes in VSWR, which were reflected back to the transistor collector circuit causing changes in the output of the amplifier.

Table 2 Output Power, Frequency and Noise Versus Temperature

°C	P_{OUT} dBm	DC CURRENT MA	FREQUENCY MHz	WAVE ANALYZER - MV				RANDOM NOISE BURSTS
				1 kHz	10 kHz	20 kHz	50 kHz	
70	16.0	500	10509.855	3.5	1.0	.9	1.8	Low Level
60	17.0	500	10509.852	1.5	.6	.7	1.3	Low Level
50	17.0	500	10509.847	1.7	.7	.7	1.2	Low Level
45	18.0	510	10509.868	1.7	.7	.75	1.2	Low Level
40	20.0	525	10509.868	1.8	.75	.75	1.3	Low Level
35	22.0	540	10509.866	2.0	.7	.7	1.2	Low Level
30	23.0	545	10509.870	2.5	.7	.8	1.2	Low Level
25	24.0	550	10509.868	1.9	.7	.7	1.3	Low Level
20	24.5	555	10509.871	2.0	.7	.75	1.4	Low Level
15	24.5	550	10509.873	1.9	.7	.75	1.4	Low Level
10	24.2	550	10509.871	3.0	.6	.7	1.0	Low Level
0	5.0	660	10509.864	2.4	.55	.6	1.0	Low Level

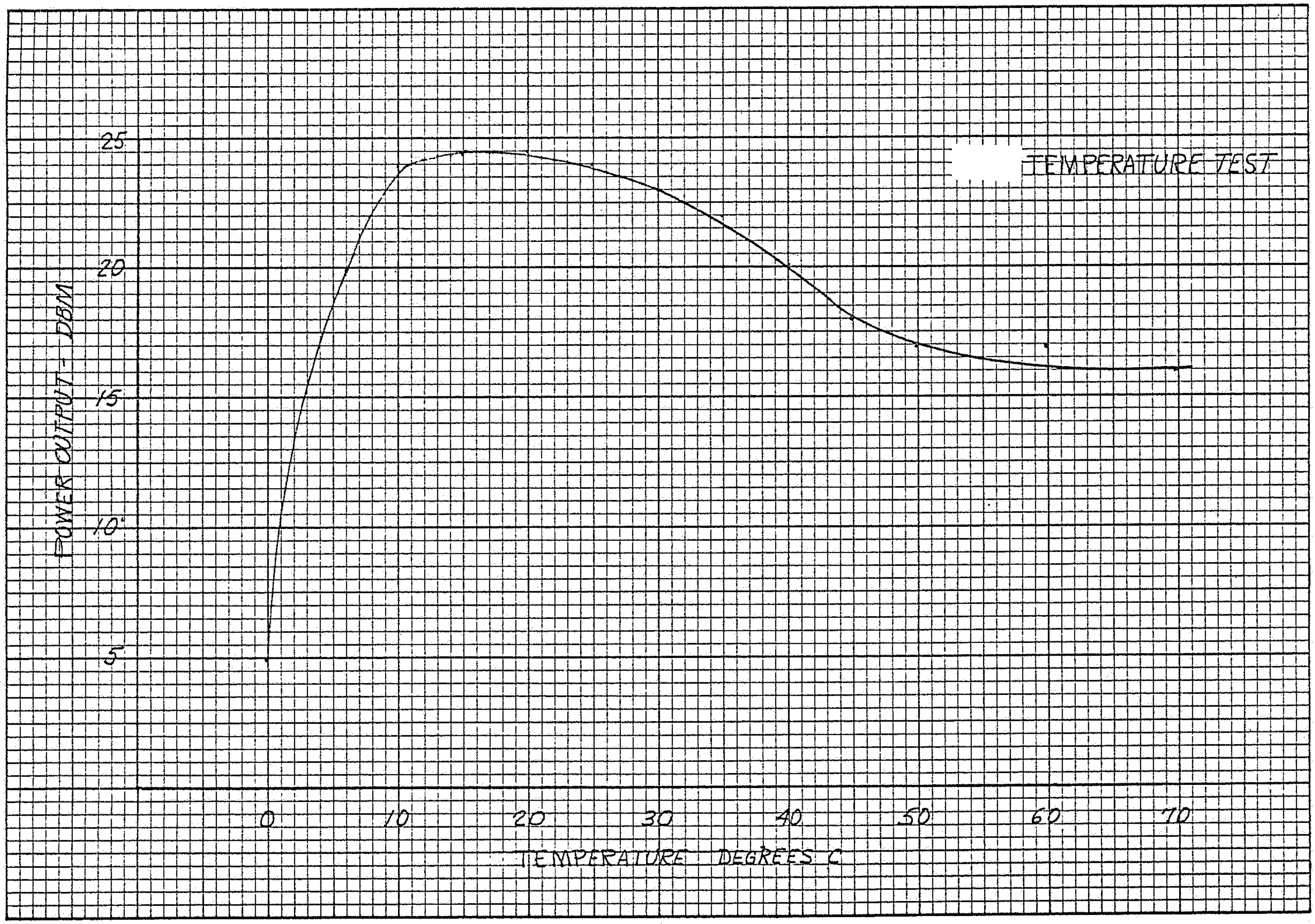


Figure 16 Temperature Test, Power Versus Temperature

The possible causes of the impedance change were:

Tuning Capacitors: These capacitors are designed with a teflon rotor lock. Temperature changes in this rotor lock causes changes of the spring-finger contacts which, in turn, changes the circuit impedance match.

Differential Expansion: The difference in the coefficient of expansion between the aluminum heat sink and the circuit boards caused small mechanical changes in the output circuits of the stripline boards. The resulting mismatch was reflected back to the transistor collector circuit and, hence, the power output was modified.

3.3.3 Effects of a Rapid Change in Temperature

The generator was stabilized at a temperature where the random noise bursts were low. The temperature was changed 10°C in one minute and the noise output observed.

3.3.4 Results and Conclusions

The random noise bursts, as observed by monitoring the amplifier output of an oscilloscope, increased to a very high level. When the temperature again stabilized, the random noise output decreased. This effect is most likely caused by differential thermal expansions and can be cured by proper selection of materials and elimination of the tuning capacitor.

SECTION 4

ENGINEERING DRAWINGS, SOLID STATE GENERATOR

581T8001	-	Hybrid Ring
2	-	Plate Clamping, Hybrid Ring
3	-	Filter Section No. 1
4	-	Filter Section No. 2
5	-	Spacer Filter
6	-	Clamping Plate, Filter
7	-	Power Divider
8	-	Clamping Plate, Power Divider
10	-	Stripline Test Board
11	-	Stripline, Amp. P/C
12	-	Stripline Amp. D/C
13	-	Clamping Plate Amp.
14	-	Stripline Amp. Slide
15	-	Dual SRD
16	-	Cavity SRD
17	-	Filter, PCM
18	-	Stripline Filter
19	-	Filter Clamping Plate
20	-	Cover; Filter PCM
21	-	Cover Filter
22	-	Stripline, Amp. PCM
23	-	Stripline Cover Amp. PCM
24	-	Stripline Amp.
25	-	Filter PCM
26	-	Cover Filter
27	-	Filter
28	-	Clamping Plate
29	-	Stripline Filter PCM

581T8030	-	Cover Filter PCM
31	-	Filter
32	-	Clamping Plate, Filter
33	-	Resonator
34	-	Slug
35	-	Cavity
36	-	Cover, Cavity
37	-	Amp., PCM
38	-	Cover Amp. PCM
39	-	Amp.
40	-	Filter PCM
41	-	Cover, Filter PCM
42	-	Filter
43	-	Hybrid, Dual SRD
44	-	Termination W/G
45	-	Stub, SRD
46	-	Stripline SRD, PCM
47	-	Stripline Cover SRD, PCM
48	-	Stripline SRD
49	-	Var. Cap SRD
50	-	Branch Line Coupler, PCM
51	-	Cover, Branch Line Coupler, PCM
52	-	Detail, Branch Line Coupler
53	-	Cover, Branch Line Coupler
54	-	Multiplier x 9 PCM
55	-	Multiplier x 9 Cover
56	-	Multiplier x 9
57	-	Multiplier x 9 Cover
58	-	Multiplier x 9 Plate
59	-	Plates, Branch Line Coupler
60	-	Inductor PCM
61	-	Inductor PCM
62	-	Inductor PCM
63	-	Filter PCM

581T8064	-	Cover, Filter
65	-	Filter
66	-	Cover Filter
67	-	Filter, Clamping Plate
68	-	Amp PCM
69	-	Cover Amp
70	-	Detail Amp
71	-	Cover Amp
72	-	Clamping Plate Amp
73	-	Power Splitter
74	-	Clamping Plate
75	-	Amp Tuning Strip PCM
76	-	Detail Amp Tuning Strip
77	-	Inductor
78	-	Antenna
79	-	Inductor, Eight Turn PCM
80	-	Inductor, Detail
81	-	Ring Hybrid
82	-	Ring Hybrid
84	-	Branch Line Coupler, PCM
85	-	Branch Line Coupler, Cover PCM
86	-	Branch Line Coupler, Detail
87	-	Branch Line Coupler, Cover
88	-	Branch Line Coupler, Plates
89	-	Heat Sink
90	-	Shield
91	-	Stub, Support SRD
92	-	Plate Clamping, SRD x 9
93	-	Test Boards, SRD x 9
94	-	Test Plates, SRD
95	-	Test Plates, SRD
96	-	Diode Mount
97	-	Amp L Band
98	-	Amp L Band Cover
99	-	Amp L Band Cover

581T8100	-	Amp L Band
101	-	Amp L Band Cover
102	-	Amp L Band Cover
103	-	Amp L Band Cover
104	-	Spacer Dial, Teflon
105	-	Spacer Washer
106	-	Plate Clamping, L Band Amp
108	-	Filter
110	-	Dual SRD, SLM
111	-	Dual SRD, Cover SLM
112	-	Dual SRD and Bias
113	-	Dual SRD Cover SLM
114	-	Coupler, SLM
115	-	Coupler, SLM Back
116	-	Coupler, SLM Cover
117	-	Branch Line Coupler
118	-	Osc. Buffer Amp, Stripline
119	-	Osc. Buffer Amp, Stripline
120	-	Osc. Buffer Amp, Stripline
121	-	Osc. Buffer Amp, Spacer
122	-	Osc. Buffer Amp, Stripline
123	-	Osc. Buffer Amp Cover
124	-	Osc. Buffer Amp, Cover
125	-	Filter Blank, Stripline
126	-	Filter Blank, Detail
127	-	Mult x 9 SRD, SLM
128	-	Mult x 9 Back, SLM
129	-	Mult x 9 Cover, SLM
130	-	x 9 Mult. Choke, SLM
131	-	x 9 Mult., SLM
132	-	x 9 Mult., Input, SLM
133	-	x 9 Mult. Filter, SLM
134	-	x 9 Mult., Detail
135	-	x 9 Mult., Bottom

581T8136	-	x 9 Mult., Filter
137	-	x 9 Mult., Input Ckt
138	-	x 9 Mult., Cover
139	-	x 9 Mult., Cover
140	-	x 9 Mult., Cover
141	-	x 9 Mult., Cover
142	-	x 9 Mult., Cover
143	-	x 9 Multiplier, Heat Sink
144	-	Base Plate
145	-	Bracket
146	-	Stud
147	-	Pin, Guide
148	-	Adapter Plate
149	-	Plug