UNCLASSIFIED

AD NUMBER
AD394799
CLASSIFICATION CHANGES
TO: unclassified
FROM: confidential
LIMITATION CHANGES
TO: Approved for public release, distribution unlimited
FROM: Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; 18 NOV 1968. Other requests shall be referred to Naval Research Lab., Washington, DC.
AUTHORITY
30 Nov 1980, DoDD 5200.10; USNRL ltr 27 Dec 1981

THIS PAGE IS UNCLASSIFIED

SECURITY

MARKING

CONFIDENTIAL NRL Report 6781

The Timation I Satellite

[Unclassified Title]

Space Applications Branch
Applications Research Division

November 18, 1968

NAVAL RESEARCH LABORATORY
Washington, D.C.

CONFIDENTIAL

Downgraded at 3 year intervals.
Declassified after 12 years.

SEE INSIDE OF FRONT COVER FOR DISTRIBUTION RESTRICTIONS

CONFIDENTIAL

NRL Report 6731

AD394799

The Timation I Satellite

[Unclassified Title]

Space Applications Branch
Applications Research Division

November 18, 1968

394 799

JAN [illegible]

NAVAL RESEARCH LABORATORY
Washington, D.C.

CONFIDENTIAL

Downgraded at [illegible] year intervals
Declassified after 12 years

[illegible] COVER FOR DISTRIBUTION RESTRICTIONS

SECURITY

This document contains information affecting the national defense of the United States within the meaning of the Espionage Laws, Title 18, U.S.C., Sections 793 and 794. The transmission or revelation of its contents in any manner to an unauthorized person is prohibited by law.

In addition to security requirements which apply to this document and must be met, each transmittal outside the agencies of the U.S. Government must have prior approval of the Director, Naval Research Laboratory, Washington, D.C. 20390.

CONTENTS

ABSTRACT
(Unclassified)

An experimental navigation satellite was launched on May 31, 1967, by NRL under a program sponsored by the Naval Air Systems Command. A passive ranging technique has been used both for the navigation of fixed and moving vehicles and for the accurate transfer of time between separated points.

This report discusses the navigation principles involved but is primarily concerned with the components of the satellite.

PROBLEM STATUS

This is an interim report; work is continuing on the problem.

AUTHORIZATION

NRL Problem R04-16
Project AIR TASK A37-538-002/652-1/F019-01-01

Manuscript submitted July 31, 1968

THE TIMATION I SATELLITE
(Unclassified Title)

BACKGROUND

Before and during 1964 timekeeping devices advanced to the point where the range between two objects could be measured by one transmitting to the other. By having stable timepieces at each location the time that the received signal is obtained could be compared to the known time it was sent and the distance between the objects could be inferred from this time delay. Such a passive ranging satellite was proposed to the Naval Bureau of Weapons in 1964, and a small study project resulted. The funding was increased in fiscal years 1965, 1966, and 1967 so a launch could be made in 1967. The launch was successful and demonstrated the stability of a high-performance crystal oscillator in orbit. The resulting passive ranging technique has been used both for the navigation of fixed and moving vehicles and for the accurate transfer of time between separated points.

This report discusses the navigation principles used but is mainly concerned with the equipment used in the satellite.

NAVIGATIONAL PRINCIPLES

If the premise is accepted that a navigation clock can be kept in synchronism with a satellite clock, the navigator can then know the time delay between him and the satellite by measuring the time of arrival of a signal from the satellite. Knowing the velocity of light, he can infer the distance between himself and the satellite. If the navigator is on the surface of the earth, the constant distance sphere cuts the earth surface on a circle on which the navigator is located. If the satellite moves to a new position or two satellites are in view, the earth's surface is cut by two circles which provide two possible fixes. Since these fixes are ordinarily hundreds of miles apart, there is no problem in resolving the ambiguity.

SATELLITE CONFIGURATION AND SPECIFICATIONS

The geometrical configuration of the Timation I satellite was determined by the space available on the launch vehicle. Figure 1 shows the satellite with the heat shields extended, and Fig. 2 shows the satellite mounted on the launch vehicle. The average power available from this geometry is approximately 6 W. The power required for those components which must operate continuously, i.e., the precision oscillator, the frequency divider, and the telemetry system, is 3 W. The total power required for the system varies from 12 to 15 W depending on the ambient temperature. Since the complete system cannot be operated continuously, the satellite is designed for command turn-on with an automatic turnoff timer set for 20 min. This technique allows the satellite to be actuated for calibration and navigation demonstrations as often as it is in view from the continental U.S. without exceeding the prescribed duty cycle and safety factor for the power supply.

The ambient temperature is important to spacecraft systems in general and to Timation I in particular, since the precision oscillator performance is partly related to ambient temperature. The upper and lower temperatures within which the oscillator

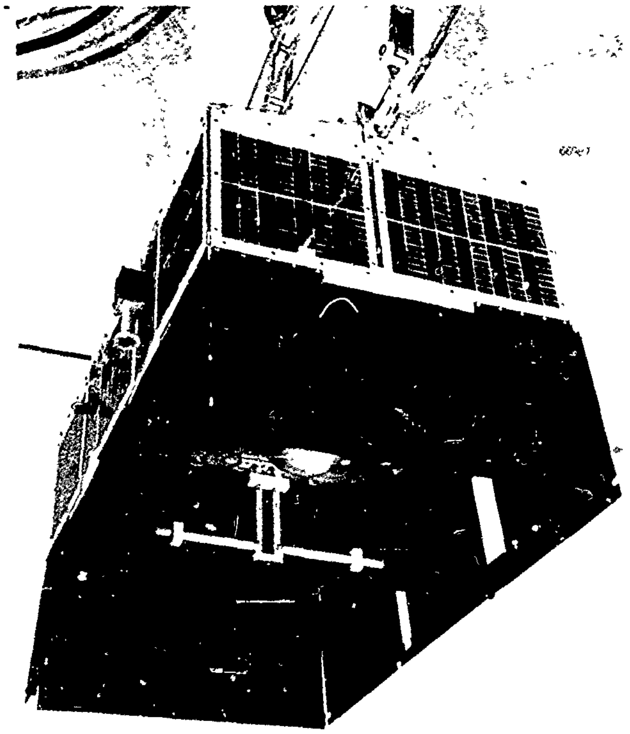


Fig. 1 - Satellite with heat shields extended

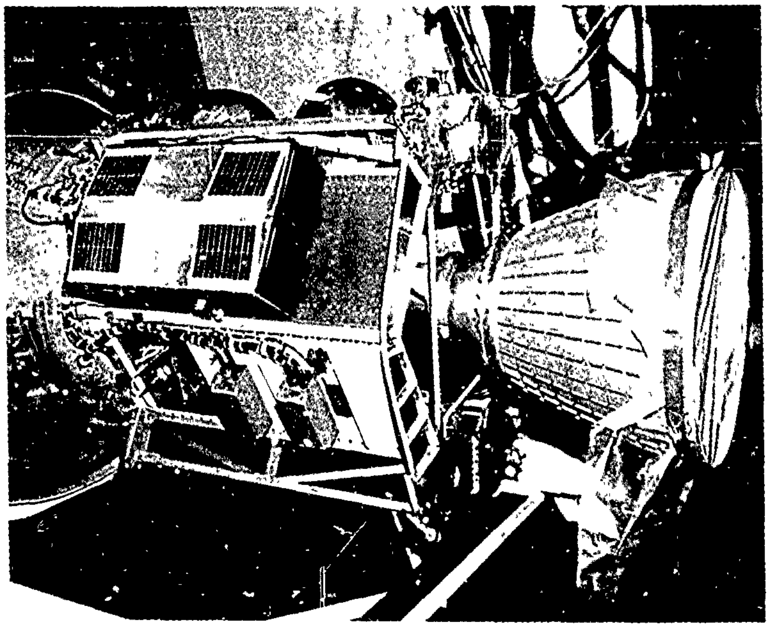


Fig. 2 - Satellite mounted on the launch vehicle

will perform are determined by the crystal oven temperature and the power available. For this satellite the operating range is from -10°C to +35°C. The final thermal design was aimed at a nominal temperature of +18°C with a minimum excursion about this point. A plot of temperature and percent time in sunlight versus time is shown in Fig. 3. The sensor for obtaining these data was fastened to the precision oscillator case.

The precision oscillator used in Timation I was procured under the following primary specifications:

Frequency	5 MHz
Stability	1 to 2 pp 10^{11}/day ±1 pp 10^{11}/load variation of ±20% ±3 pp 10^{12}/°C
Input power	±12 V dc at 1.5 W maximum
Weight	6 lb maximum
Remote frequency adjustment	
Resolution	1 pp 10^{11}/pulse
Range	1 to 2 pp 10^7 (5 yr)

SATELLITE ANTENNA

The desired pattern of the satellite antenna was one that would illuminate the earth so that at all times the satellite was above the horizon a signal would be received with only small variations in signal strength with an absence of nulls in the radiation pattern. Linear polarization was chosen for the satellite and circular polarization for the ground stations so that no cross polarization nulls would occur. A minimum of coupling to the telemetry antennas was desired, since the transmitter was radiating a relatively large amount of power, and coupling between the 400-MHz radiating antenna and the telemetry antennas could interfere with the proper operation of the telemetry receiver.

The coupling between the 400-MHz transmitter antenna placed on the side of the satellite that was to face the earth and the telemetry antennas which were mounted on the edges was approximately 40 dB down.

The earth-seeing face of the satellite was used as a ground plane for the dipole, which was large enough to have an appreciable ground effect but was not so large as to produce deep nulls in the plane of this surface. Because of size restrictions, the antenna was placed close to the gravity gradient stabilizing boom. This placement had little effect, because the radiating portion of the dipole was horizontally polarized. The balun structure was placed symmetrically with respect to the boom so that no unbalancing of the balun would be caused by the presence of the boom. The dipole was placed slightly less than one-quarter wavelength above the ground plane face (5 in.) to make maximum use of the relatively small ground plane and to improve the match of the dipole. The length of the elements was trimmed slightly to compensate for the shortening effect and off-center feed of the balun. A special mechanical and electrical arrangement at the feed point of the dipole was developed to insure maximum strength at the feed point and to allow the connection of coaxial cable by means of fittings. This cable also allowd the dipole to pivot, without rotary joints, from a position against the ground screen to an upright position. The entire dipole assembly could be replaced or inspected by

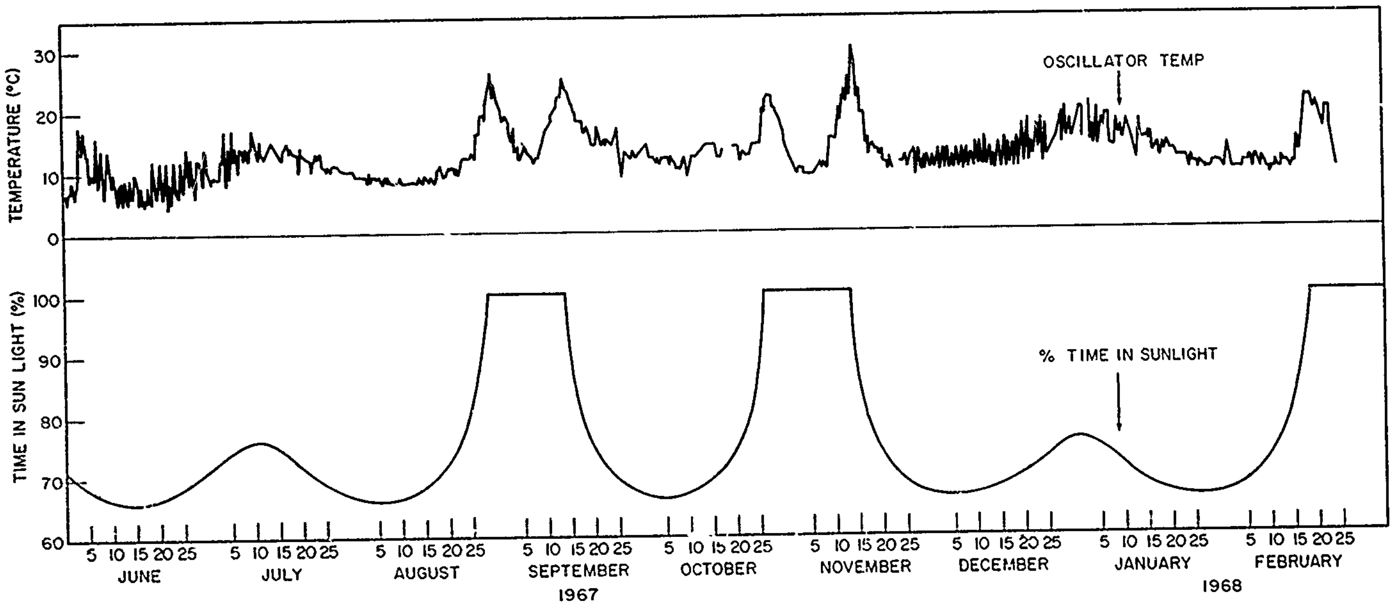


Fig. 3 - Temperature and percent of time in sunlight versus time for the period May 31, 1967, through February 15, 1968

unscrewing the various components. A Teflon block at the top of the dipole carried the mechanical stress. High-temperature Teflon coaxial cable was used to insure proper operation in the possible wide extremes of temperature environment (-70°C to +70°C). The coaxial cable and the spring required to erect the antenna after launch are carried in two hollow legs of the balun structure. Figure 4 shows the dipole in its folded position.

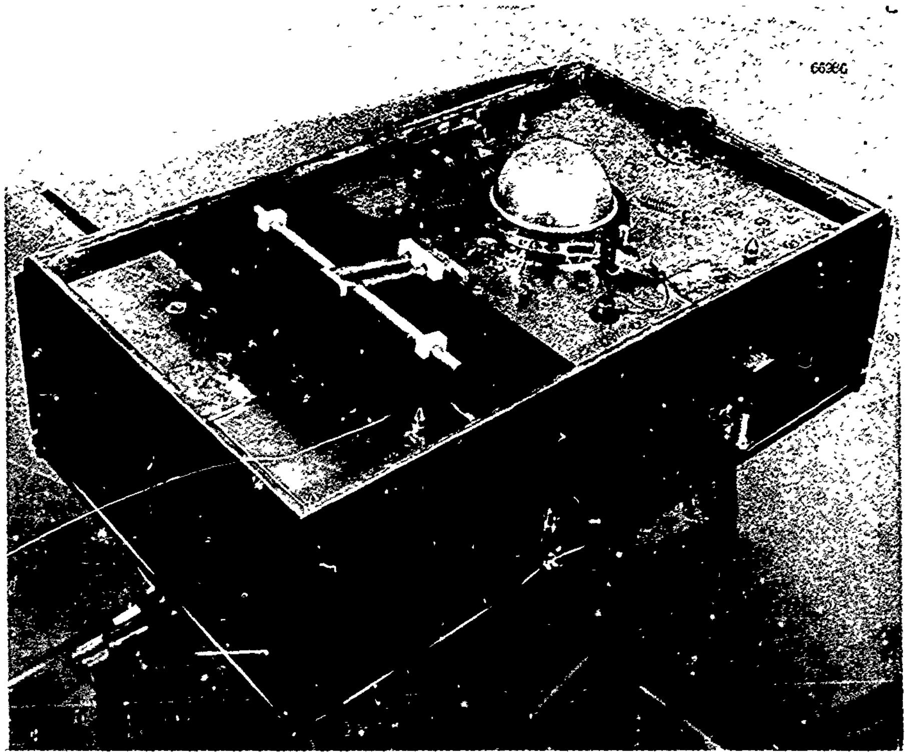


Fig. 4 - Dipole in its folded position

As linear polarization is transmitted from the satellite, the circular polarization on the ground will produce a pattern free from nulls except in the case when circular polarization of the opposite sense is generated in the ionosphere. This probability seems to be very small because the two components would have to be equal in amplitude and 90 degrees out of phase. The experimental results of this geometry on this satellite has shown that nulls very rarely occurred when this antenna configuration was used.

SATELLITE SYSTEM

The principal design considerations for Timation I were high efficiency and high reliability. Figure 5 is a block diagram of the complete system. The heterodyne process is used throughout, and frequency multiplication is used only as a common vehicle for the superposition of these tones to the proper end frequency. As a result, phase instability due to the multiplication process remains coherent except for the small second-order effects due to noise, intermodulation products, etc., of the various separate circuits. Figure 6 shows the basic layout of the principal components.

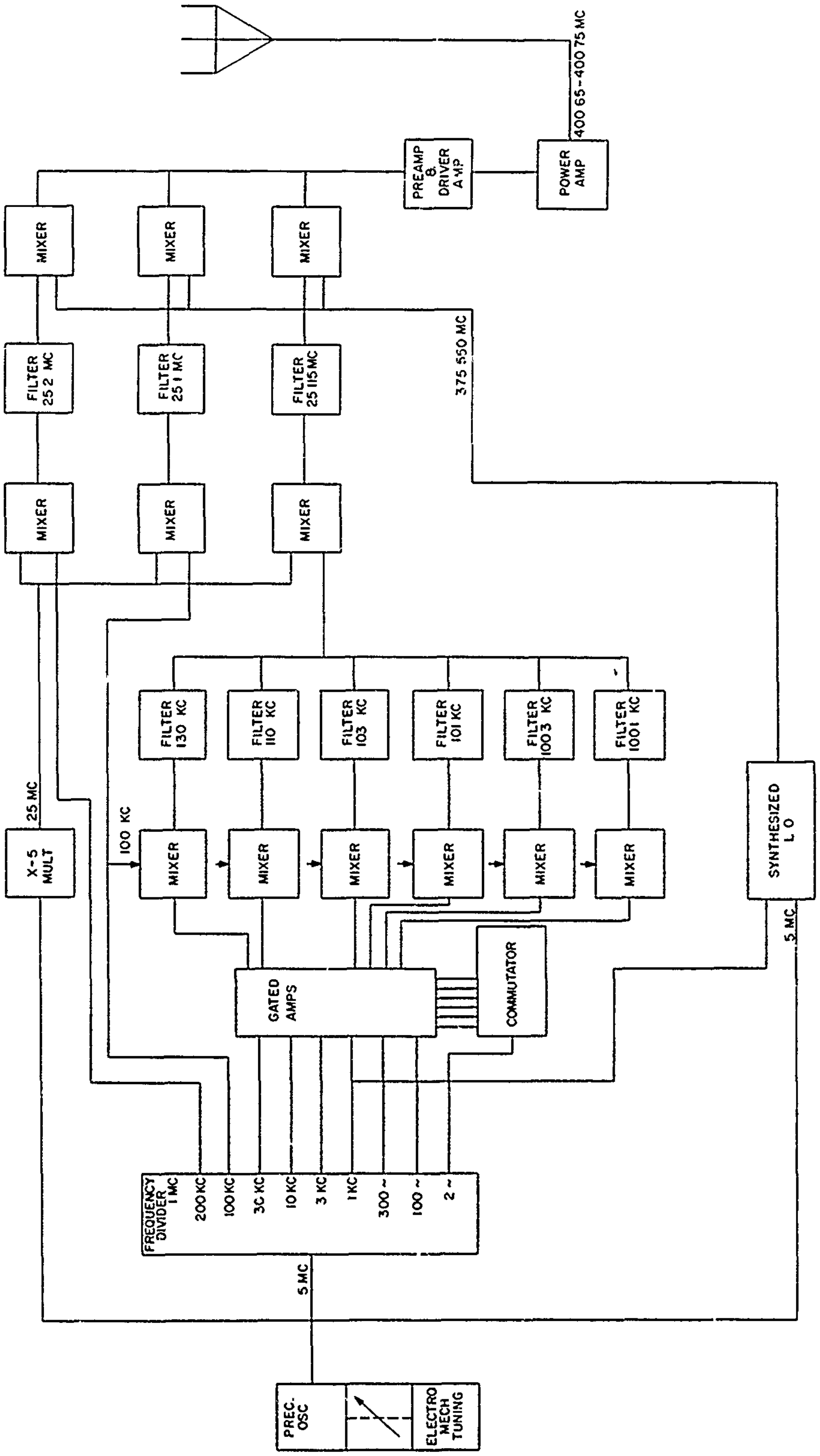


Fig. 5 - Complete satellite system

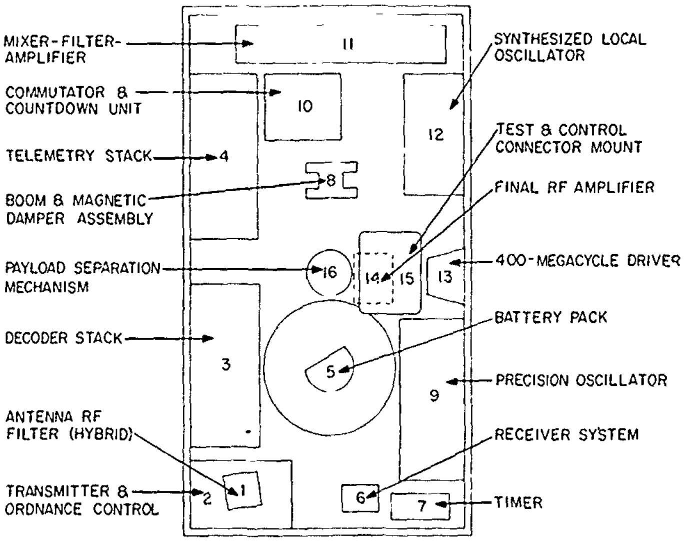


Fig. 6 - Layout of the principal components of the satellite system

FREQUENCY DIVIDER

The 5-MHz-to-2-Hz divider (Fig. 7) system is implemented with low-power diode transistor logic (DTL) integrated circuits. Logic circuits used are reset-set-trigger (RST) flip-flops, dual input, dual gates, and four input buffer drivers. The basic logic configuration is a divide-by-five counter, used in conjunction with single flip-flops acting as divide-by-two counters to obtain the required frequency division ratios. All signal outputs are isolated from the logic through logic gates to better than 30 dB.

The 5-MHz input signal is divided down to 1 MHz. The 200-kHz, 100-kHz, 10-kHz, 1-kHz, 100-Hz, and 2-Hz outputs are obtained by successive division of the 1 MHz in the proper ratios.

A three-time multiplication of the 200 kHz to 600 kHz is then divided down to obtain the 30-kHz, 3-kHz, and 300-Hz outputs.

The relative differential phase between all output signals is held to 1% or less over the temperature range of 5°C to 25°C and a dc voltage variation of 25%. Input power to the divider unit is 850 MW. Output signals are square waves with 50% duty cycle at 3 V peak to peak into 50 ohms.

MIXER-FILTERS-AMPLIFIERS

By using the 100-kHz tone to produce the base or reference frequency of 400.650 MHz and the 200-kHz tone to produce the 100-kHz difference frequency of 400.750 MHz, heterodyning of the 100-Hz through 30-kHz tones with 100 kHz defined the prime spectral relationship of each tone.

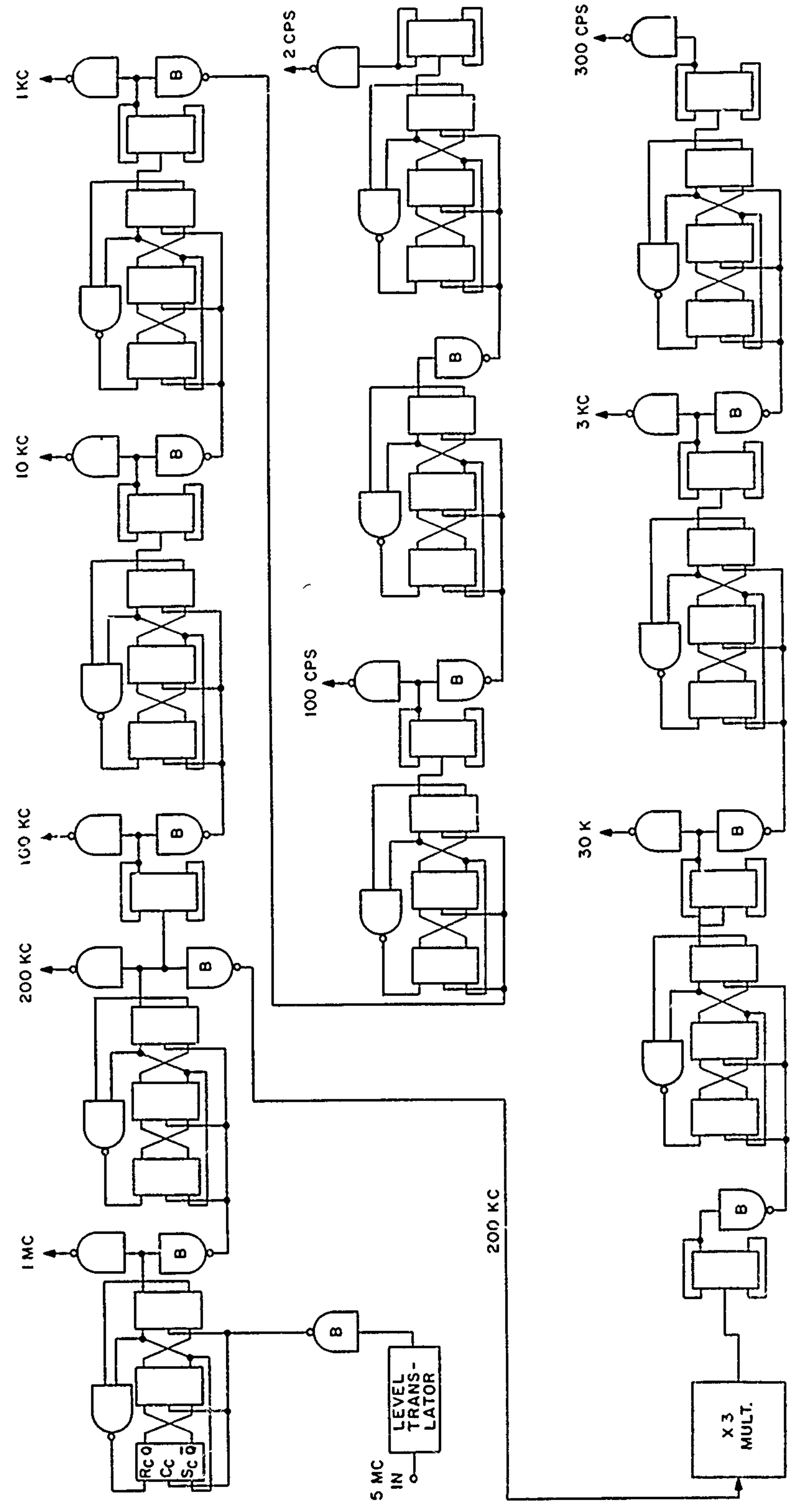


Fig. 7 - Frequency divider

COMMUTATOR-GATED AMPLIFIERS

The 2-Hz output of the frequency divider is used as a time base for commutating all subtones below 100 kHz. Low-power DTL circuitry consisting of three binary dividers that are reset on the sixth count with dual AND gates providing the logical sequence of signals to their respective mixers, is shown in Figs. 8 and 9.

A coincident one count on lines B1, B4, and B5, for example, not only puts the base of the following Darlington in a latch up state but also gates in the 100-Hz tone to the proper channel. Using this configuration, better than 40 dB of isolation from the related tones was obtained.

Figure 10 shows the actual processes that the various initial outputs of the 5-MHz precision source and the output tones of the frequency divider underwent to arrive at the 25-MHz region.

The 100-kHz signal is fed into a seven-way active distribution amplifier board for mixer application. Port-to-port isolation is in excess of 40 dB. This isolation presents the harmonically related tones from appearing in other channels during the mixing process. Each of the commutated tones is fed to separate mixers and the upper sideband is selected by crystal filtering. (Every filter was specified to provide phase coherence with temperature.)

Derivation of the 25-MHz signal from the fifth overtone of the 5-MHz source provided the necessary second conversion injection frequency for translation of all tones from the 100-kHz region to the 25-MHz region. To maintain channel isolation through signal injection ports of the three common 25-MHz distribution systems, hybrid lumped constants and/or resonant traps were used. This provided in excess of 30 dB of interchannel isolation.

The three 25-MHz mixers provided translation of the 100-kHz signal to 25.1 MHz, the 200-kHz signal to 25.2 MHz, and the commutated tones of 25.0001, 25.0003, 25.001, 25.003, 25.010, and 25.030 MHz commonly through the third mixer. In each case the upper sideband was selected with crystal filters.

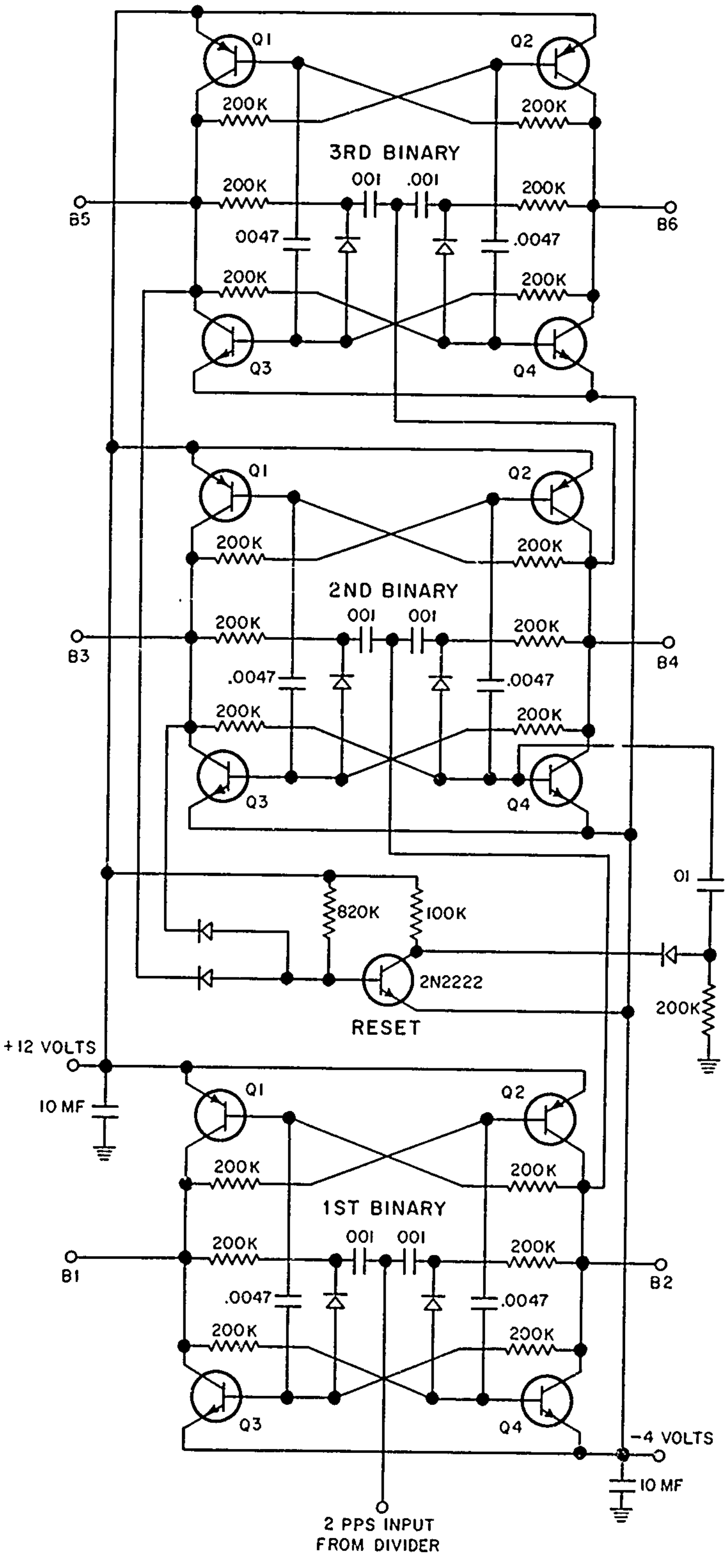
SYNTHESIZED LOCAL OSCILLATOR

To derive the 375.55-MHz signal (Figs. 11, 12, and 13) the eleventh harmonic of the 1-kHz square-wave tone was extracted passively by feeding it directly into two 11-kHz ceramic filters connected in cascade and then doubling this frequency to 22 kHz.

The third harmonic of the 5-MHz source (15 MHz) and the 22-kHz source were then mixed and filtered for the upper sideband of 15.022 MHz and multiplied in two consecutive five-time stages to 375.55 MHz. Three outputs were provided through hybrid isolation circuitry with output levels of 2 MW.

PREAMPLIFIERS - 400-MHz MIXERS

The 25-MHz tones and 375.55-MHz tones were combined in a set of selective and separate mixers as shown in Fig. 14. This provided maximum isolation between signal paths. After amplifying each signal to its former level a resistive summing network was incorporated, and all tones were cascade-amplified to the 2-W level.



Q1, Q2 - 2N2907
Q3, Q4 - 2N2222
DIODES - IN662

Fig. 8 - Binary board

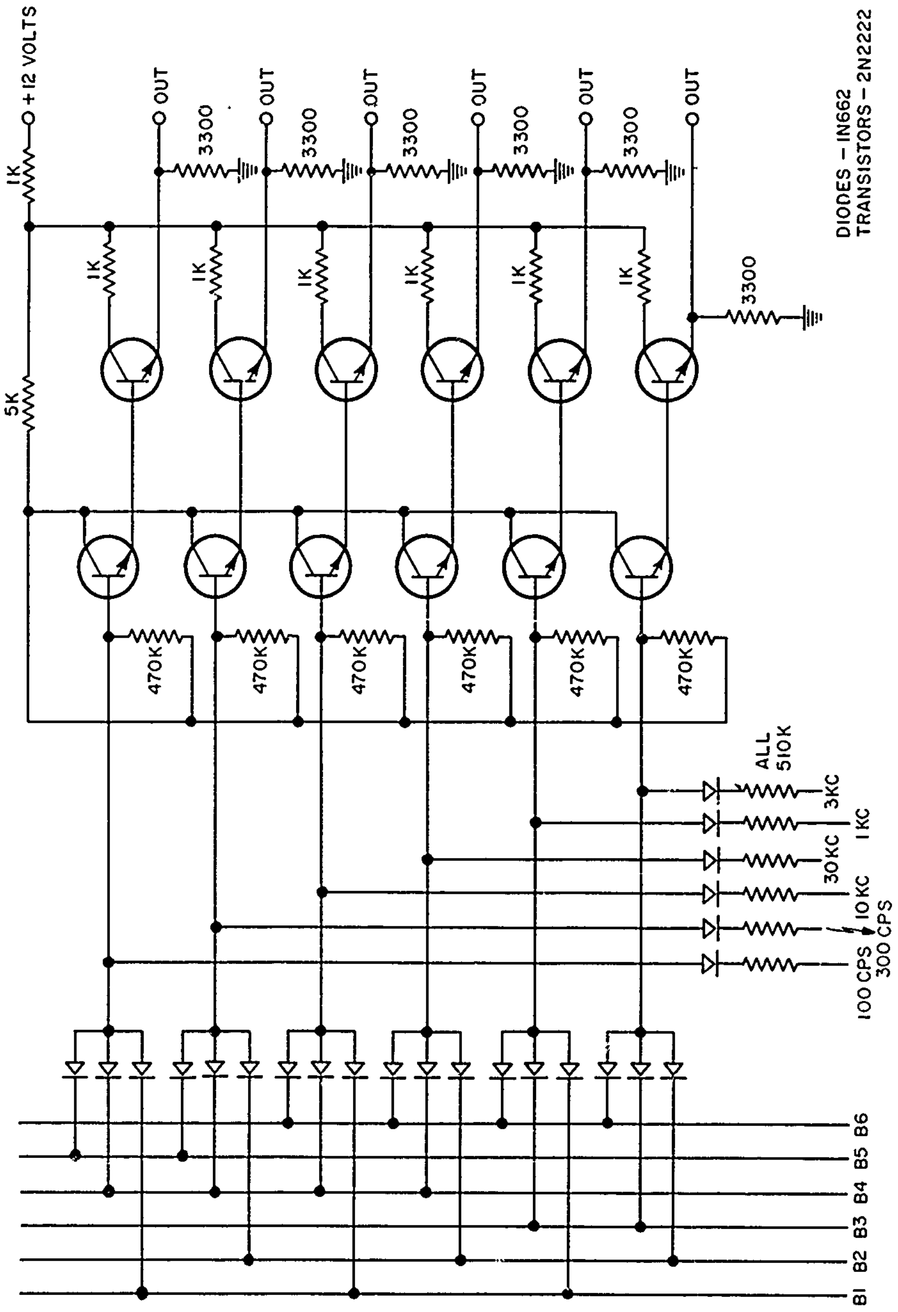


Fig. 9 - Commutator board

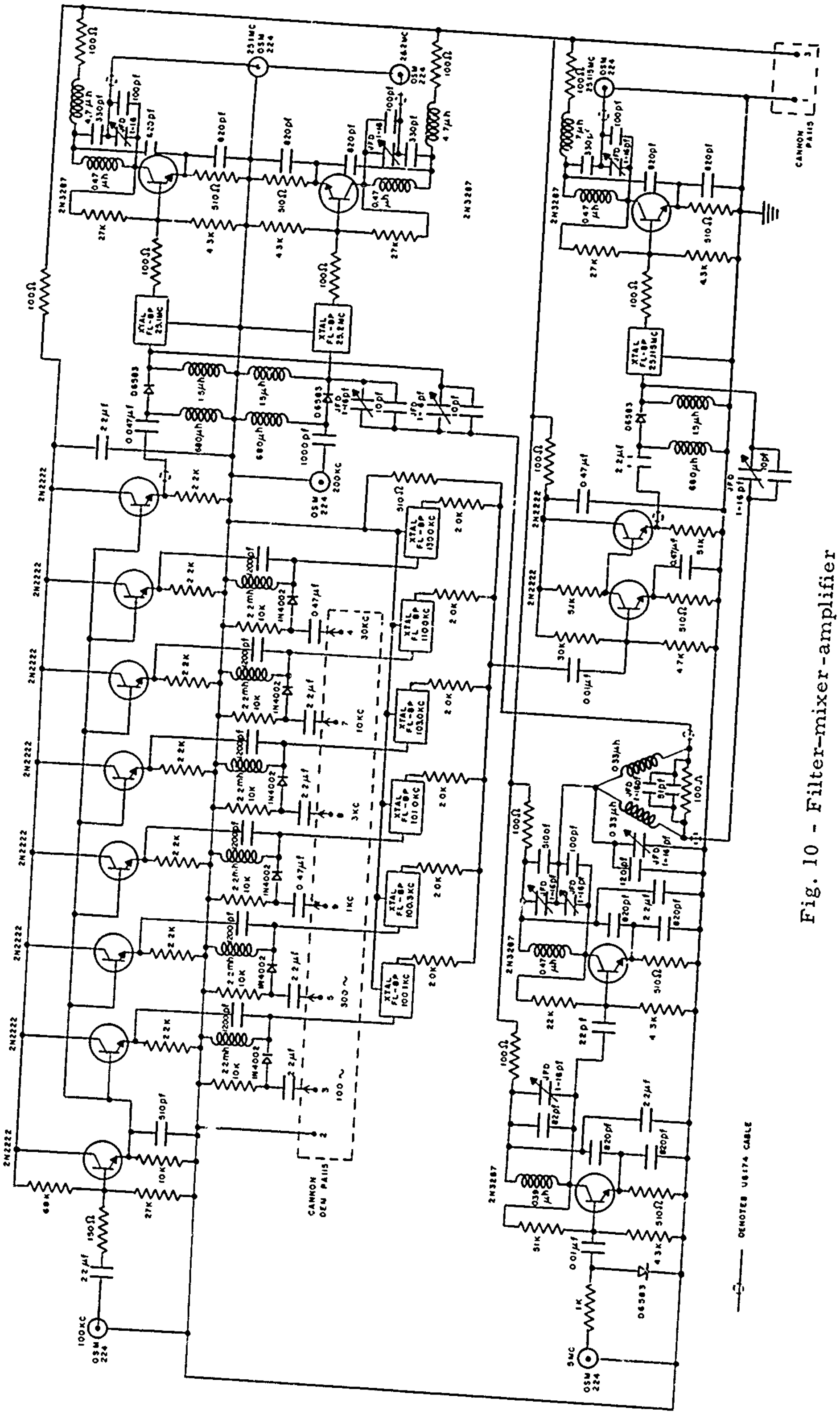
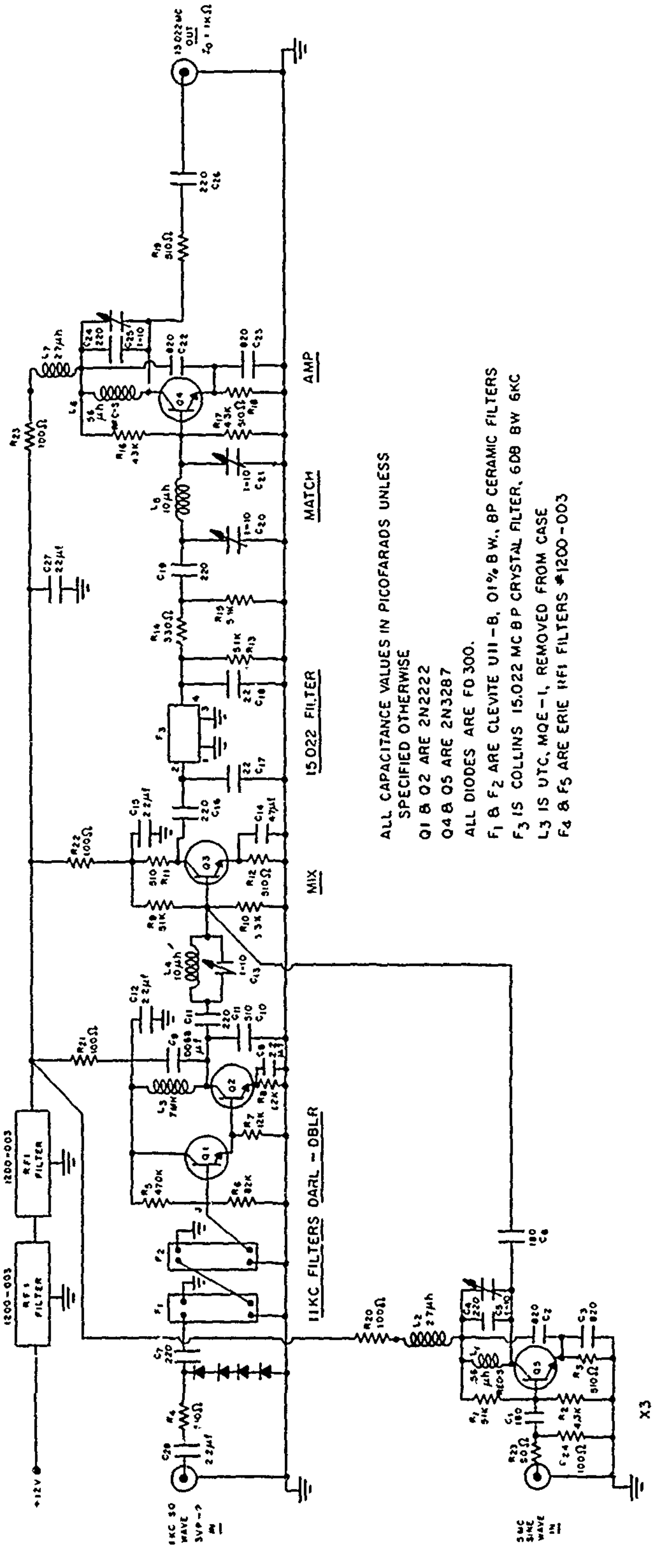
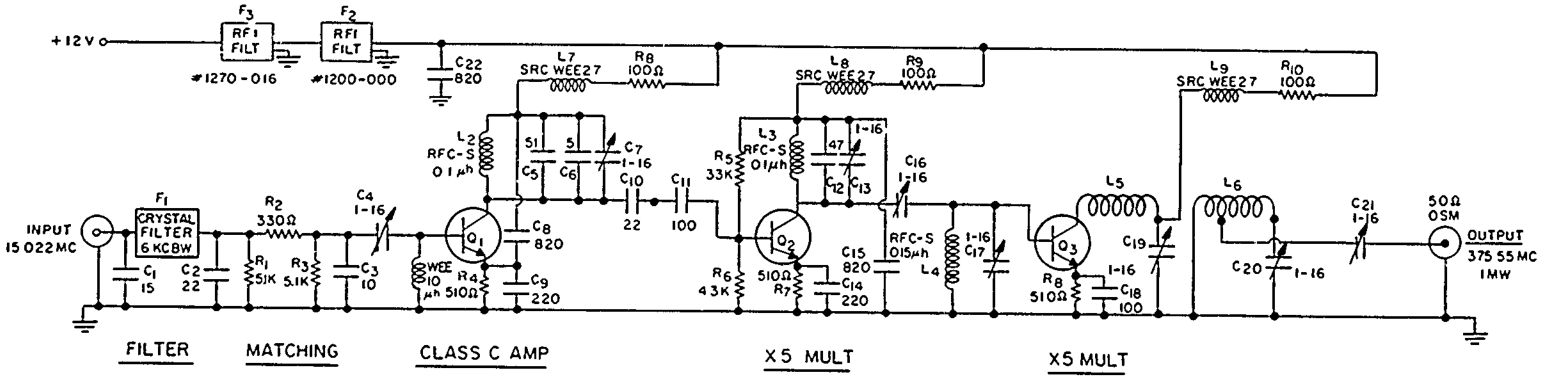


Fig. 10 - Filter-mixer-amplifier



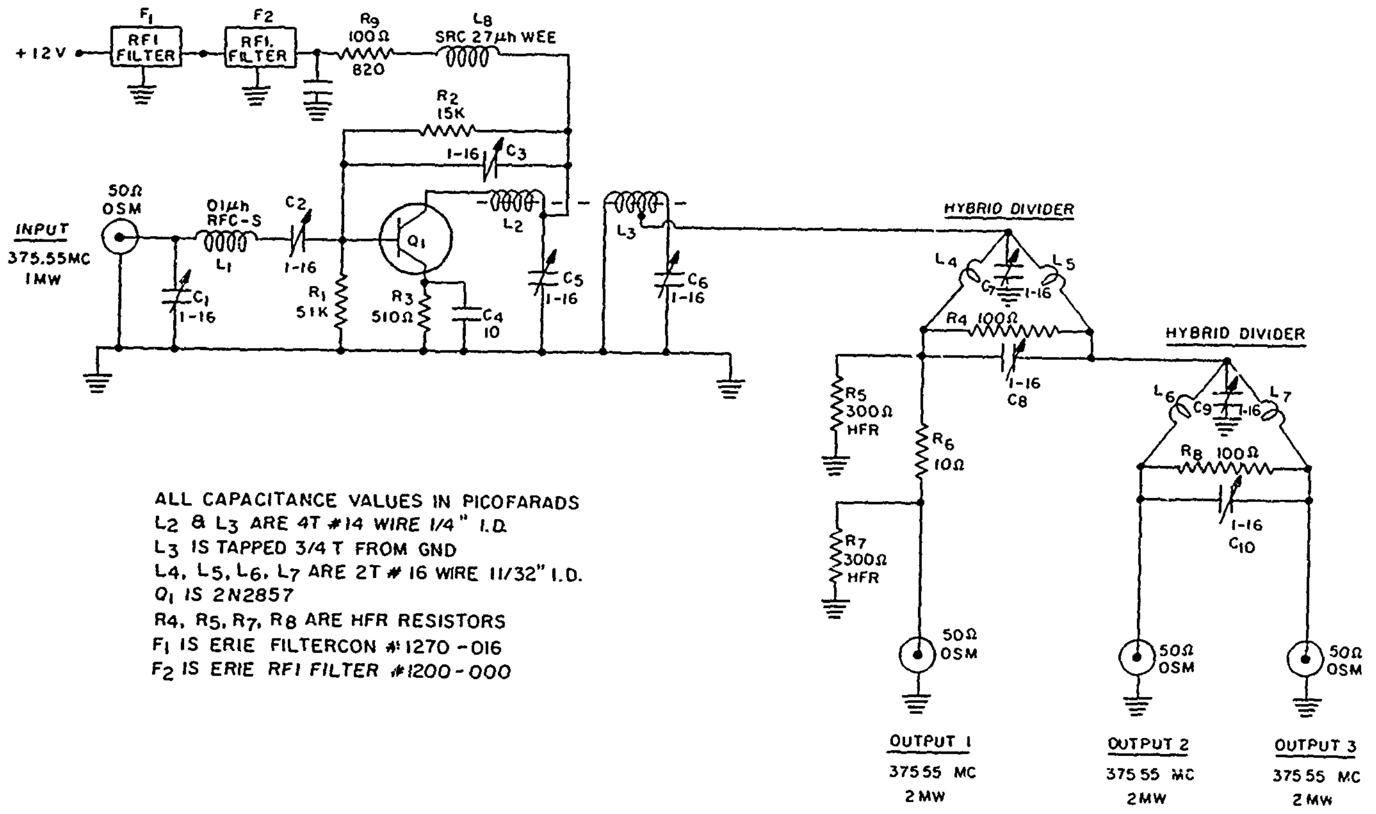
ALL CAPACITANCE VALUES IN PICOFARADS UNLESS
SPECIFIED OTHERWISE
Q1 & Q2 ARE 2N2222
Q4 & Q5 ARE 2N3287
ALL DIODES ARE FD 300.
F_1 & F_2 ARE CLEVITE U11-B, .01% B.W., BP CERAMIC FILTERS
F_3 IS COLLINS 15.022 MC BP CRYSTAL FILTER, 6DB BW 6KC
L3 IS UTC, MQE-1, REMOVED FROM CASE
F_4 & F_5 ARE ERIE RFI FILTERS #1200-003

Fig. 11 - Board 1 synthesizer



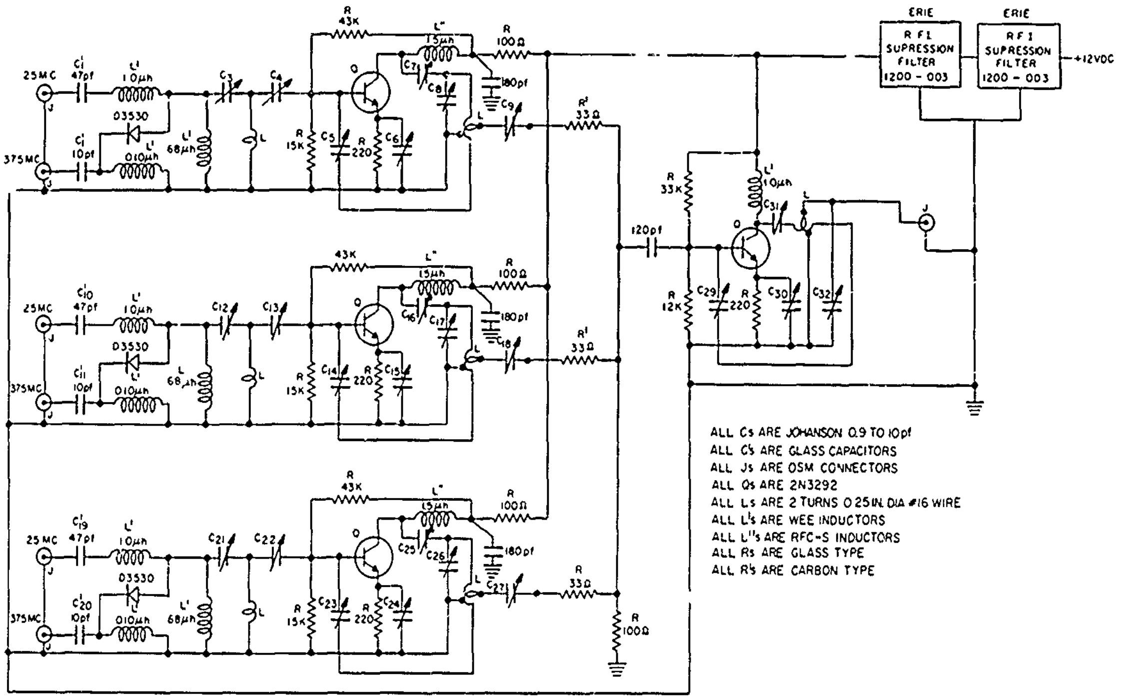
ALL CAPACITANCE VALUES IN PICOFARADS
L_5 & L_6 ARE 4 T #14 WIRE 1/4" I.D.
L_6 IS TAPPED 3/4 T FROM GROUND
C_{11} IS DURAMIC (SMALL)
CRYSTAL FILTER IS COLLINS 15.022 BAND PASS
6 DB BW OF 6 KC & 60 DB BW OF 16 KC
Q_1 & Q_3 ARE 2N3292
Q_2 IS 2N2857
F_1 IS COLLINS 15.022 MC B.P. CRYSTAL FILTER, 6 DB BW 6 KC
F_2 IS ERIE RFI FILTER #1200-000
F_3 IS ERIE FILTERCON # 1270-016

Fig. 12 - Board 2 multiplier



ALL CAPACITANCE VALUES IN PICOFARADS
L_2 & L_3 ARE 4T #14 WIRE 1/4" I.D.
L_3 IS TAPPED 3/4 T FROM GND
L_4, L_5, L_6, L_7 ARE 2T # 16 WIRE 11/32" I.D.
Q_1 IS 2N2857
R_4, R_5, R_7, R_8 ARE HFR RESISTORS
F_1 IS ERIE FILTERCON #1270-016
F_2 IS ERIE RFI FILTER #1200-000

Fig. 13 - Board 3 amplifier-divider



ALL Cs ARE JOHANSON 0.9 TO 10pf
ALL C's ARE GLASS CAPACITORS
ALL Js ARE OSM CONNECTORS
ALL Qs ARE 2N3292
ALL Ls ARE 2 TURNS 0.25 IN. DIA #16 WIRE
ALL L's ARE WEE INDUCTORS
ALL L''s ARE RFC-S INDUCTORS
ALL Rs ARE GLASS TYPE
ALL R's ARE CARBON TYPE

Fig. 14 - 400-MHz mixer

FINAL STAGES OF 400 MHz

The 400-MHz amplifier section was made up of four separate cascade stages having an overall gain of 33 dB and a 3-dB bandwidth of approximately 7 MHz. Considerable difficulty was encountered with the high-powered stages, as shown in Fig. 15, with oscillation, regeneration, and impedance matching with changing input level and/or temperature.

The inherent input matching problem for overlay transistors was solved to a satisfactory degree by the selection of lossy ferrite material for the base return and short emitter returns. Final stability was acquired in the final stage with a collector damping network as shown.

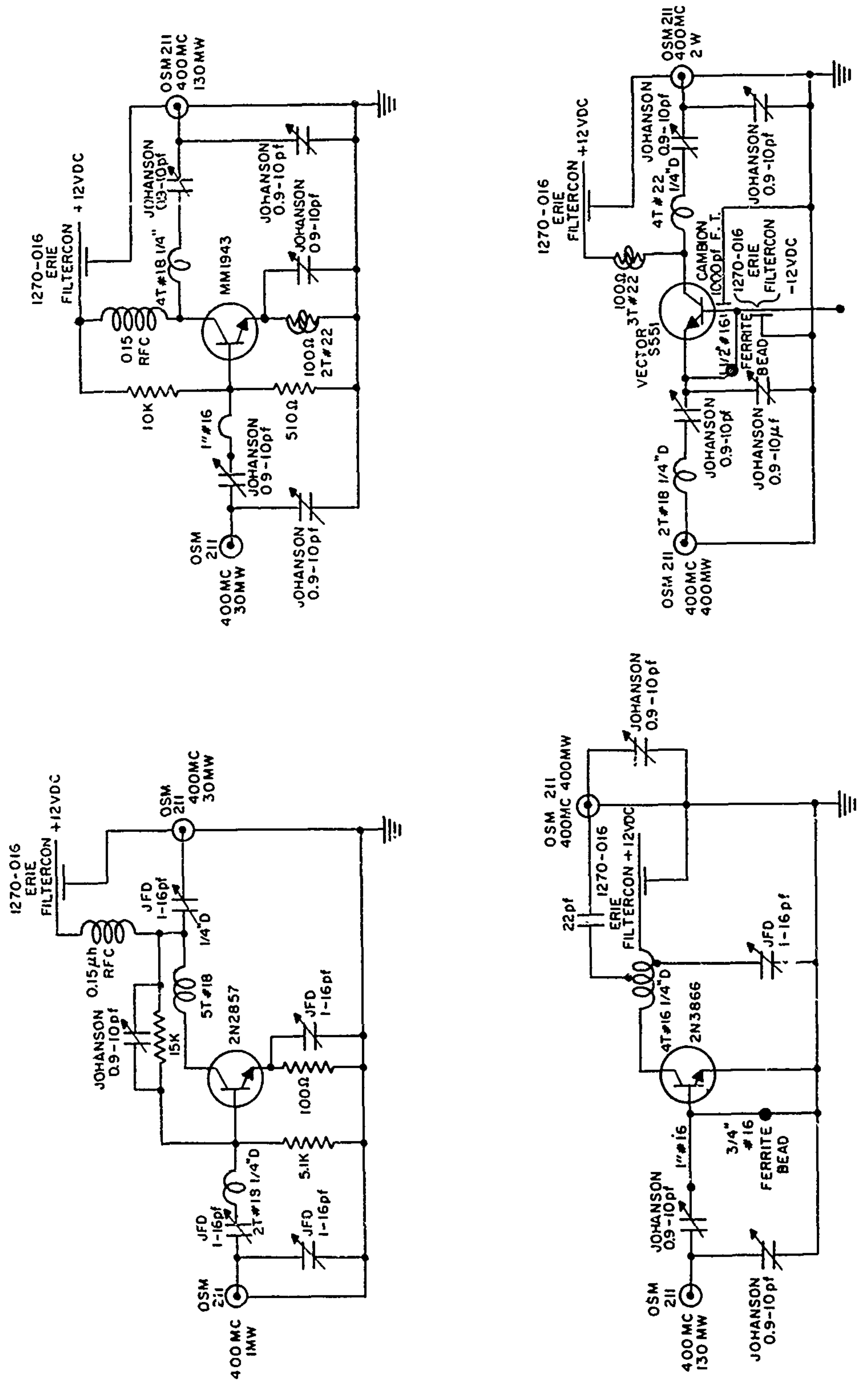


Fig. 15 - 400-MHz amplifiers

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)*
Naval Research Laboratory
Washington, D.C. 20390

2a. REPORT SECURITY CLASSIFICATION
Confidential

2b. GROUP
4

3. REPORT TITLE
THE TIMATION I SATELLITE (U)

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*
Interim report; work is continuing on the problem.

5. AUTHOR(S) *(First name, middle initial, last name)*
Space Applications Branch

6. REPORT DATE
November 18, 1968

7a. TOTAL NO OF PAGES
22

7b. NO OF REFS
0

8a. CONTRACT OR GRANT NO
NRL Problem R04-16

b. PROJECT NO
A37-538-002/652-1/F019-01-01

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)
NRL Report 6781

9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*

10. DISTRIBUTION STATEMENT
In addition to security requirements which apply to this document and must be met, each transmittal outside the agencies of the U.S. Government must have prior approval of the Director, Naval Research Laboratory, Washington, D.C. 20390.

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY
Department of the Navy (Naval Air Systems Command), Washington, D.C. 20360

13. ABSTRACT

(Unclassified)

An experimental navigation satellite was launched on May 31, 1967, by NRL under a program sponsored by the Naval Air Systems Command. A passive ranging technique has been used both for the navigation of fixed and moving vehicles and for the accurate transfer of time between separated points. (U)

This report discusses the navigation principles involved but is primarily concerned with the components of the satellite. (U)

DD FORM 1 NOV 65 1473 (PAGE 1)
S/N 0101-807-6801

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Satellites Navigation principles						

DD FORM 1 NOV 65 1473 (BACK)
(PAGE 2)