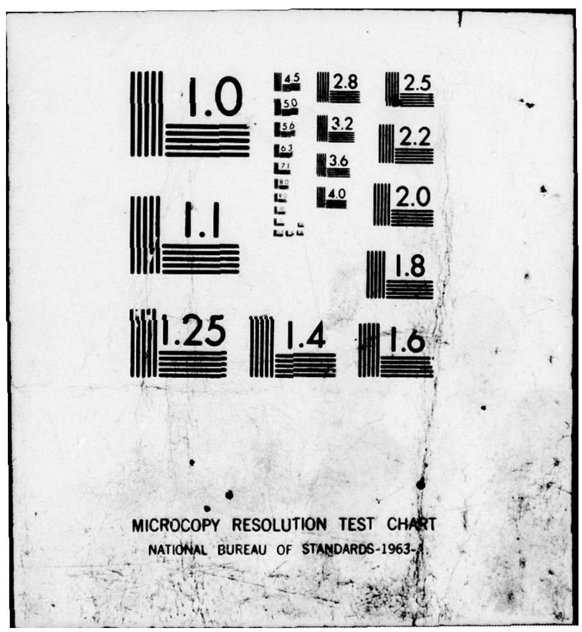
AD-A073 666 TEXAS UNIV AT AUSTIN DEFENSE RESEARCH LAB F/G 17/9
SEA, LAND, AND RAIN CLUTTER MEASUREMENT II,(U)
FEB 67 D W COULBOURN
UNCLASSIFIED DRL-548 NL

| OF |
AD
A073666

END
DATE
FILMED
10-79
DDC


1.0
4.5
5.0
5.6
6.3
7.1
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

DEFENSE RESEARCH LABORATORY

THE UNIVERSITY OF TEXAS
AUSTIN, TEXAS 78712

DRL-548

SEA, LAND, AND RAIN CLUTTER MEASUREMENT II (U)

by

Dixon W. Coulbourn

9 February 1967

Copy No. [redacted]

A Technical Report Prepared under
APL/JHU Subcontract 181471, Task G,
Authorization Nos. G-3 through G-5

DEFENSE RESEARCH LABORATORY
THE UNIVERSITY OF TEXAS
AUSTIN, TEXAS 78712

ABSTRACT

A phase-stable pulse radar system with dual frequency and dual range modes of operation was built to study radar clutter. Tests using the radar have resulted in sea and rain clutter data which are being analyzed by APL/JHU. Instrumentation of the radar was covered in DRL-537 "Sea, Land, and Rain Clutter Measurement" dated 3 May 1966. The present report covers modifications made to the system in 1966. It describes rain clutter measurements made in Austin and sea clutter measurements made in Galveston, Texas, and Cape Cod, Massachusetts.

CONFIDENTIAL

TABLE OF CONTENTS

		Page
ABSTRACT		ii
I.	INTRODUCTION	1
II.	MODIFICATIONS MADE TO CLUTTER MEASUREMENT EQUIPMENT	2
	A. Illuminator	2
	1. Dymec 2654A Synchronizers	6
	2. Frequency Converter	6
	3. 1 kW Traveling-Wave Amplifier	8
	4. Klystron Sources	13
	B. Synchronizing System	16
III.	RAIN CLUTTER MEASUREMENTS AT AUSTIN	19
IV.	GALVESTON SHAKEDOWN TRIP	20
V.	CLUTTER MEASUREMENT PROGRAM AT CAPE COD	21
	A. Transportation	21
	B. Setting Up Exercises	21
	C. Site Geometry and Geography	21
	D. Polarization Error	27
	E. Clutter Measurement	27
VI.	CONCLUSIONS	34
APPENDIX A		36
APPENDIX B		39

I. INTRODUCTION

This report describes the work done under Contractor's Work Authorization Nos. G-3 through G-5, APL/JHU Subcontract No. 181471, Task G.

II. MODIFICATIONS MADE TO CLUTTER MEASUREMENT EQUIPMENT

The clutter measurement equipment was described in a previous report.[1] During 1966 the following modifications were made to the system to increase its effectiveness. The transmitted power was increased from 20 W to 1000 W. An improved frequency offset method makes possible more rapid adjustment of frequency. Variable-range receiver blanking prevents baseline shift due to receiver saturation by spillover and nearby targets, and variable RF attenuators in the receiver permit optimizing signal level. A photograph of the system installed in the van appears in Fig. 1.

A. Illuminator

The present illuminator block diagram is shown in Fig. 2. Output power is 1 kW for frequency separations of 0 to 500 MHz, and 20 W for a frequency separation of 2.64 GHz. Frequency offsets from 1 kHz to 20 MHz can be switched in a 1,2,5 sequence. Two klystrons, phase stabilized by Dymec 2654A synchronizers, provide reference and offset frequencies. The reference is phase-locked to a harmonic of the 5 MHz from the GR1115B frequency standard. The alternate frequency is locked to a harmonic plus an offset determined by a switched crystal oscillator. The advantages of this technique over the use of the multiplier and offset synchronizer used formerly are

(1) Freedom from spurious harmonics--The varactor multiplier was sensitive to drive level, power supply voltage, and temperature, and therefore was not well suited to the changing conditions which it experienced.

(2) Independence of sources--The offset synchronizer locked a klystron's frequency at an offset from the reference frequency by phase-comparing the reference and the klystron's frequency. Therefore, if the multiplier broke into a spurious mode, the klystron broke lock.

---

[1] "Sea, Land, and Rain Clutter Measurement," DRL-537, 3 May 1966.

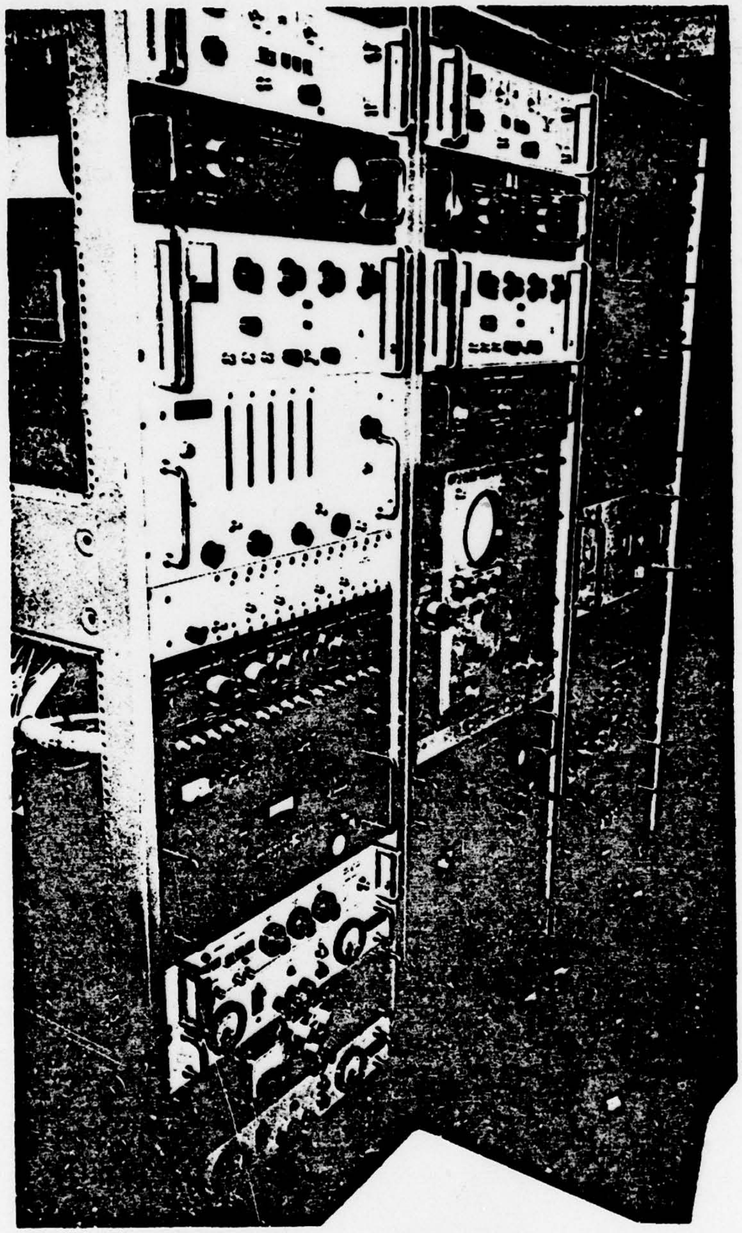


FIGURE 1
CLUTTER MEASUREMENT EQUIPMENT

181471-G-47

CONFIDENTIAL

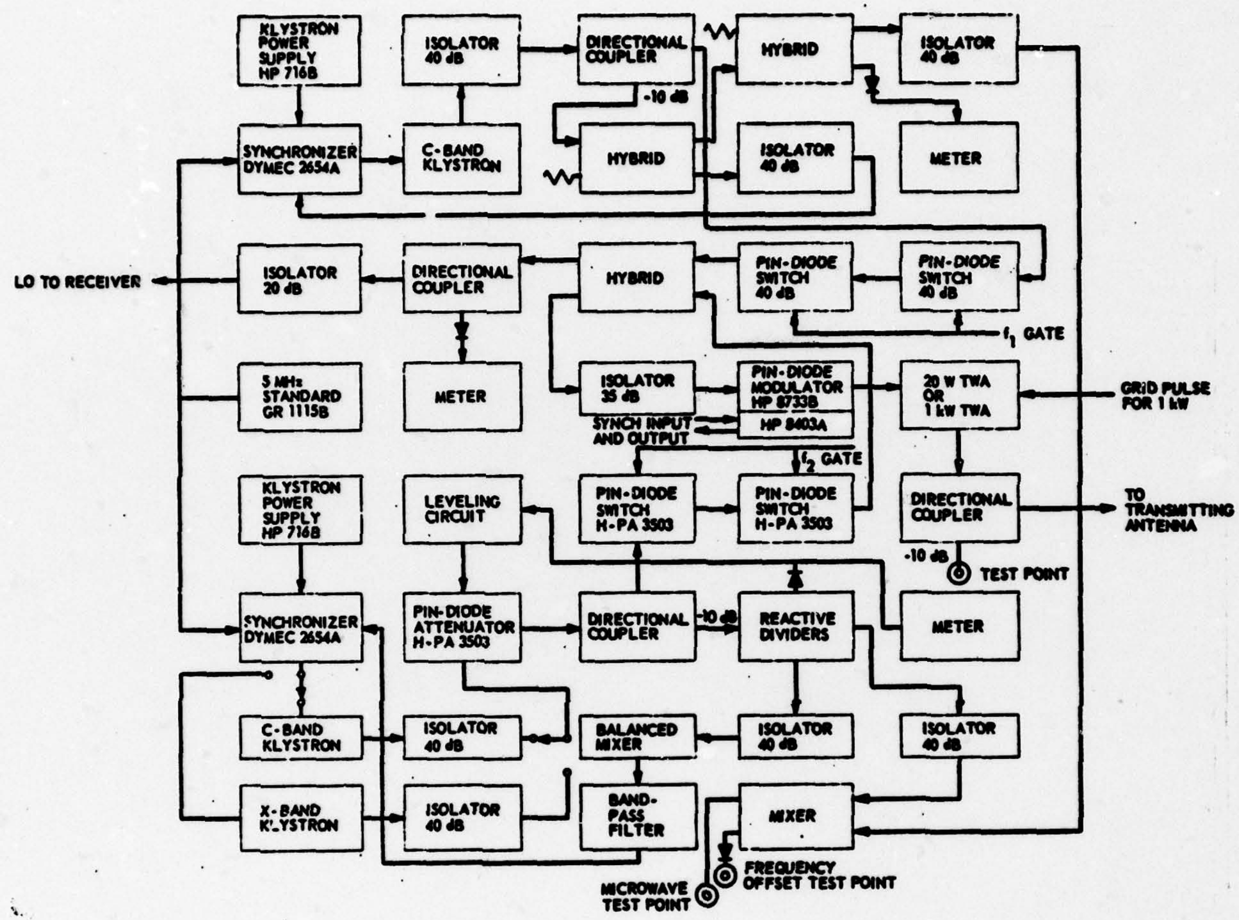


FIGURE 2
ILLUMINATOR BLOCK DIAGRAM

DRL - UT
DWG AE-67-1
DWC - RFO
1 - 26 - 67

CONFIDENTIAL

(3) Wide variation of offset frequency--Using the offset frequency to make phase measurements and correct the klystron led to difficulty at low offsets, when the offset frequency approached the band of klystron FM noise. In order to filter the phase detector ripple sufficiently the response of the correction loop became too slow to correct the klystron's FM. At offsets above 2 MHz the wide-band phase detector was unable to supply a large enough output to lock the klystron readily. The use of the Dymec synchronizer in the present system solved both of these problems. All phase detection is done at a single frequency, the 30 MHz IF of the Dymec. This is high enough to be well above any FM noise of the klystron, and the Dymec provides a large correction voltage, ±20 V, which provides a strong lock.

(4) Increased power--One hundred mW of power is needed to drive the 1 kW tube. If the 20 W TWA power supply fails, as it did at Cape Cod, the klystrons can provide sufficient power to drive the 1 kW tube directly, whereas the multiplier provides only 20 mW of output power.

The advantage of increased transmitter power is not only the increased sensitivity for low sea states but increased range of operation. In order to approximate open sea conditions, the water depth should be at least one-half a sea wavelength deep. Some of the wavelengths measured at Cape Cod were as much as 250 ft. A water depth of 125 ft was not reached at Cape Cod except at ranges of 3 miles or more.

Details of operation of added equipment are given below.

(5) 5 MHz Frequency Standard--The GR1115B replaces the H-P 103AR formerly used on loan from another DRL section. The GR1115B has a lower noise pedestal and has a 5 MHz output, eliminating the need for a 1 to 5 MHz frequency multiplier. The oscillator has a built-in battery floated across its dc power supply. This enables the oscillator to maintain maximum stability despite nightly shutdown.

1. Dymec 2654A Synchronizers[2]

A block diagram of the DY2654A Frequency Standard Synchronizer is shown in Fig. 3. In the Synchronizer a sample of the klystron's output is mixed with a harmonic spectrum derived from the 24th harmonic (120 MHz) of the GR1115B 5 MHz output to generate a difference frequency IF of 30 MHz. This is amplified, limited, and applied to a phase comparator, where it is compared with a 30 MHz signal also obtained from the 5 MHz standard. The resultant phase-sensitive output voltage is used to correct the klystron oscillator frequency.

Since the operation is independent of whether the difference frequency is obtained by having the klystron oscillator 30 MHz above or below the selected harmonic, N, the output of the reference klystron can therefore be any value that satisfies the expression

$$f_1 = 120N \pm 30 \text{ MHz} \quad .$$

As the klystron oscillator is tuned throughout its range, locking will occur at 60 MHz intervals, each lock point frequency being an odd multiple of 30 MHz.

Synchronization of the klystron is facilitated by the search oscillator which automatically sweeps the frequency of the free-running klystron such that the klystron need only be tuned to enter the lock range of the synchronizer for capture to occur. When the klystron is locked the search oscillator automatically turns off.

2. Frequency Converter

Offset frequencies are set by translating the sampled microwave frequency to a lock point 60 MHz above (or below) the reference klystron

[2]"Engineering Data," Model 2042A, Dymec, Palo Alto, Calif.

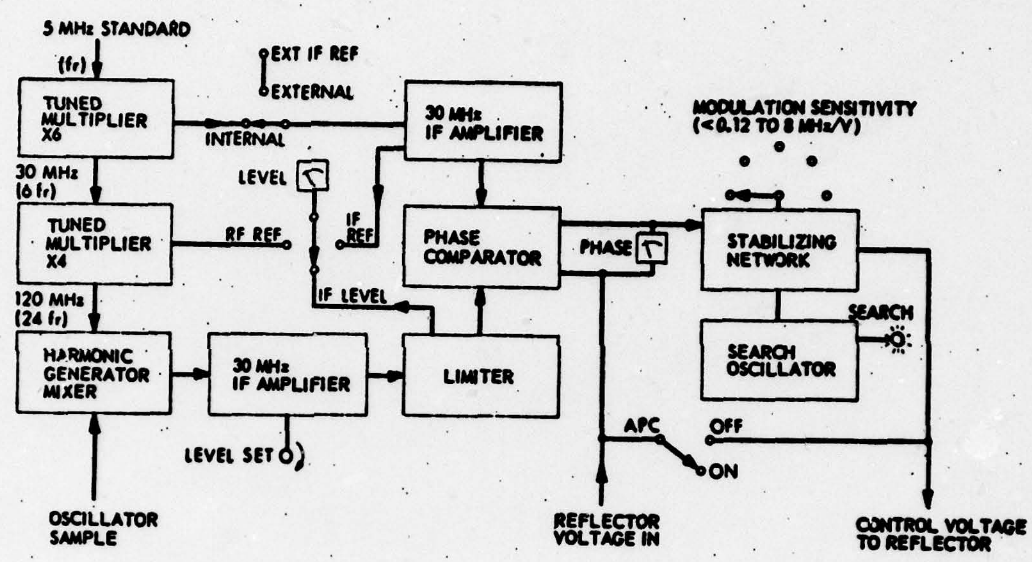


FIGURE 3
BLOCK DIAGRAM OF
DYMEC 2654A SYNCHRONIZER

DRL - UT
DWG AE-67-2
DWC - RFO
1 - 27 - 67

lock point. The frequency converter block diagram is shown in Fig. 4. Its operation is as follows. The klystron is tuned mechanically to the desired frequency, $f_2 = f_1 \pm \Delta f$, in which f_1 is the reference frequency and Δf is the offset frequency. The crystal oscillator is switched to (60 MHz - Δf), which is mixed with the sampled klystron frequency, ($f_1 \pm \Delta f$). One sideband, ($f_1 \pm \Delta f$) $\pm$ (60 MHz - Δf), is selected by the band-pass filter and fed to the synchronizer sample input. The synchronizer has lock points at 60 MHz intervals and therefore locks the klystron as though its frequency were $f_1 \pm$ 60 MHz. The two frequencies f_1 and f_2 are heterodyned in another mixer to permit monitoring the frequency offset. An oscilloscope is used to obtain a check on the frequency offset.

3. 1 kW Traveling-Wave Amplifier

A power supply was built for the ZM3144 traveling wave tube, which had been built for the TYPHON program. The photograph of the power supply appears in Fig. 5. A schematic diagram of the unit is shown in Fig. 6. The tube is powered by a Universal Voltronics BRE-10-80 power supply, which provides up to 10 kV at 80 mA. The BRE-10-80 has been adapted to this use by incorporation of a pulse-mode circuit which enables the regulating circuit to operate properly with the power supply connected across the 5 μF energy storage capacitor. The power supply also has a built-in Variac in its primary circuit so that the energy storage capacitor can be brought up to operating voltage without exceeding the power supply rated current.

The energy storage capacitor was chosen to maintain supply voltage across the ZM3144 tube constant within 10 V, which corresponds to approximately 2 deg of phase; however, in normal operation, phase stability is somewhat better. Assuming that the tube is being operated at its long-term duty cycle limit and at a repetition rate of 6 kHz, a maximum anode current of 1.07 A and a 1.17 μsec current pulse width, the voltage across the 5 μF capacitor will drop

$$\frac{(1.07\ \text{A})(1.17 \cdot 10^{-6}\text{sec})}{(5.10^{-6}\text{F})} = 0.25\ \text{V during each pulse.}$$

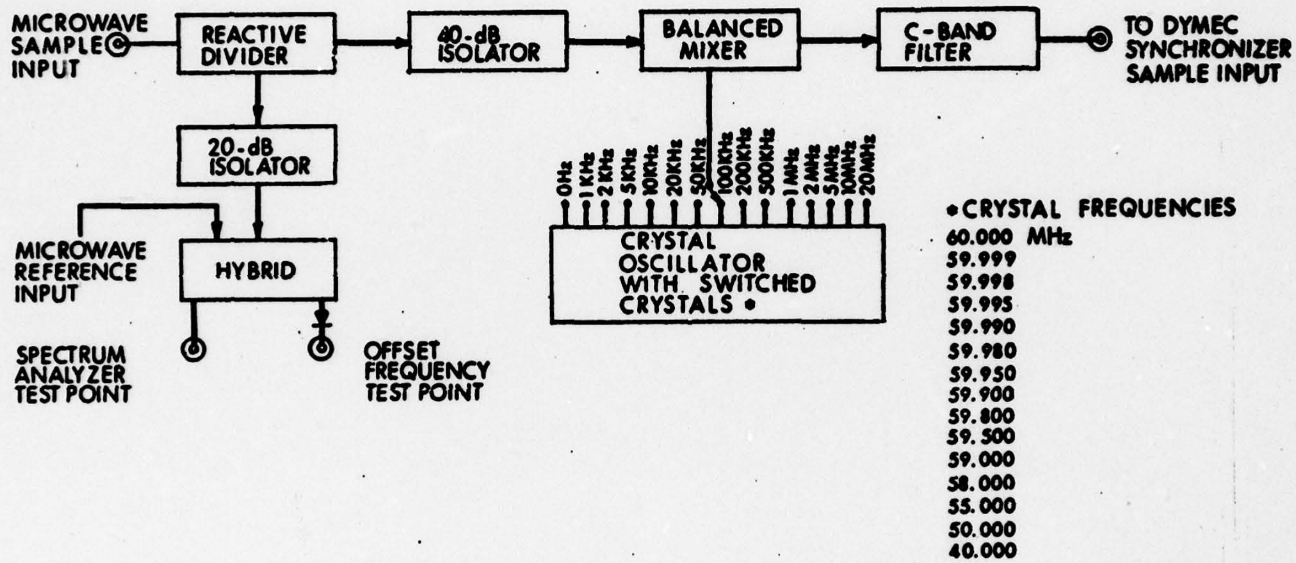


FIGURE 4
C-BAND FREQUENCY CONVERTER(U)

DRL - UT
DWG AE-66-158
DWC - ORS
8 - 10 - 66
REV 1 - 26 - 67

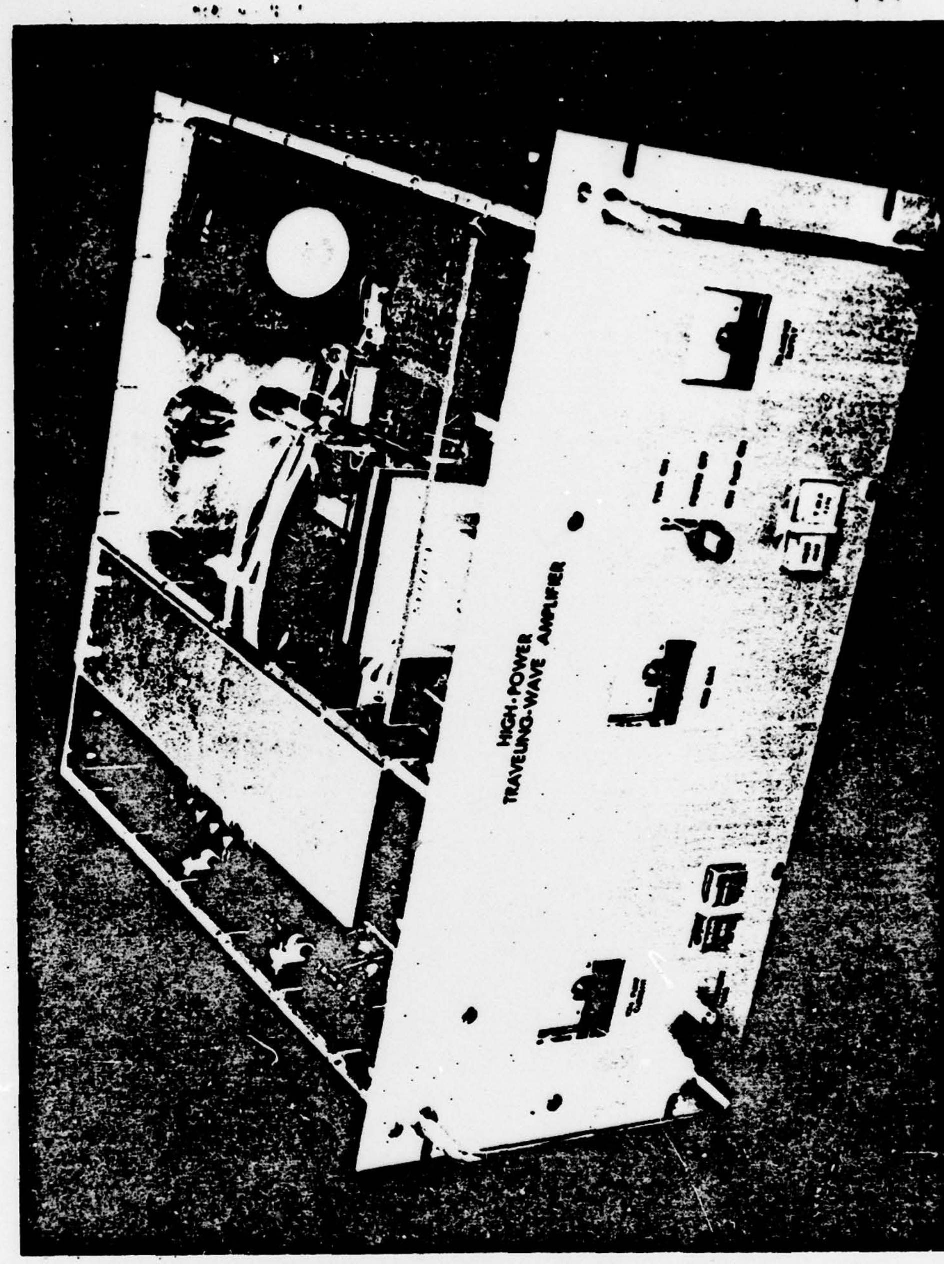


FIGURE 5
1-kW TRAVELING WAVE AMPLIFIER
FRONT VIEW

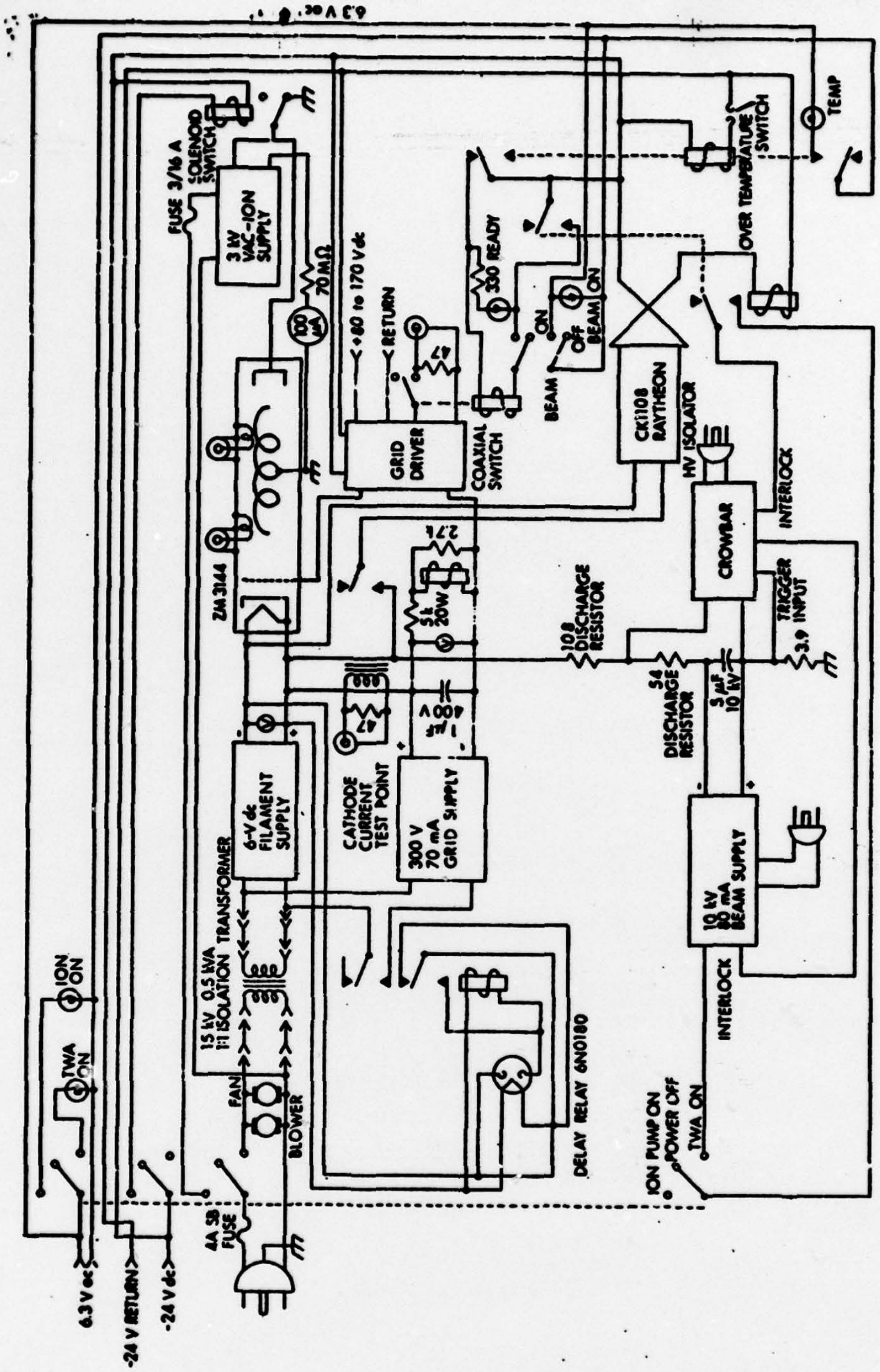


FIGURE 6
1-kW TRAVELING WAVE AMPLIFIER SCHEMATIC (U)

DRL-UT
DWG AE-66-181
DWC-RFO
10-24-66

The BRE-10-80 regulated power supply will respond in approximately 2 msec so that the voltage across the capacitor will drop no more than

$$(0.25\ V)(2 \cdot 10^{-3}sec)(6 \cdot 10^{3}\ Hz) = 3\ V \quad ,$$

corresponding to 0.6 deg, at 100 mW of drive. The capacitor has an inductance of 0.06 μH. At a turn-on time of 0.5 μsec, L di/dt ≅ 0.12 V, which is negligible. The RF pulse width is determined by the H-P 8733B Pin modulator which forms an RF pulse bracketed by the TWT grid pulse.

The tube is protected by a crowbar circuit which places a short across the tube in case the beam current becomes excessive and also shuts off the beam supply. Other safeguards include an over-temperature switch which shuts off the grid pulse in case of overheating, and interlocks to prevent the application of potentials in incorrect order. An ion pump supply is provided to maintain the vacuum when the TWA is off.

Operation of the amplifier is as follows. With the front panel switch in the position TWA ON, the regulated dc filament supply and the two fans turn on. A 3-min delay relay is actuated by the filament voltage. A six-V relay is actuated at the end of the 3-min period, cutting out the delay relay heating element and switching on line voltage to the grid bias supply. Line voltage for the filament and grid bias supplies is isolated from ground by a 1:1 transformer which is insulated for 15 kV. These supplies are floated at cathode potential. When the grid bias supply reaches a sufficient level a 28-V relay is actuated, supplying 6 V dc from the filament supply to the Raytheon CK1108 High Voltage Isolator. The isolator output resistance is controlled by the isolator input voltage. Twenty-eight volts applied to the interlock relay through the isolator ON resistance causes this relay to close. This, in turn, closes an interlock in the beam supply, provided the crowbar interlock is closed. Grid pulses are inhibited if the grid bias is not present or if the over-temperature switch closes. In case of overheating the grid pulse is interrupted until the heat sink cools 15°F. Cathode current pulses can be observed using the crowbar input test point, which is across the

3.9-ohm resistor between the energy storage capacitor positive terminal and ground. In case of arcing or other causes of excessive current in the TWA, a voltage is developed across this resistor, triggering the crowbar unit. Within a few microseconds the crowbar thyratron is triggered, initiating a current limited by the 54-ohm discharge resister. The 108-ohm discharge resistor between the TWT and the thyratron prevents a short in the TWA from loading the thyratron and preventing its firing. The three resistors also limit arc current available to the TWT.

The heat sink for the traveling wave tube consists of an aluminum channel with 165 1-1/2 in. aluminum screws fastened to the inside of the web. The tube is screwed down to the other side which has been surfaced to make good thermal contact. The channel is covered to act as a duct for the blower, which is also fastened to the heat sink. No overheating was experienced during the Cape Cod tests.

The grid driver schematic is shown in Fig. 7. A negative 3-V pulse applied to its input gates a 375-V pulse into the grid of the TWA. The amplitude of the pulse is adjustable by varying the supply voltage applied to the driver.

4. Klystron Sources

The C-band klystron source block diagram is shown in Fig. 8. Its manual tuning point is indicated by a geared turns-counting dial. A front panel meter indicates relative power. The klystron is buffered by a 40 dB isolator. Another 40 dB isolator prevents the harmonics of 120 MHz generated in the synchronizer from reaching the frequency offset mixer, and a third 40 dB isolator prevents the reference klystron signal from reaching the synchronizer for the offset frequency klystron.

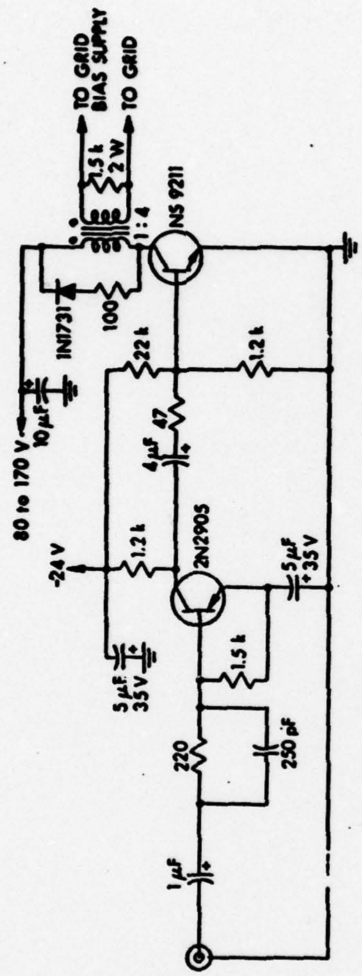


FIGURE 7
GRID DRIVER SCHEMATIC (U)

DRL - UT
DWG AE-66-182
DWC - RFO
10 - 25 - 66

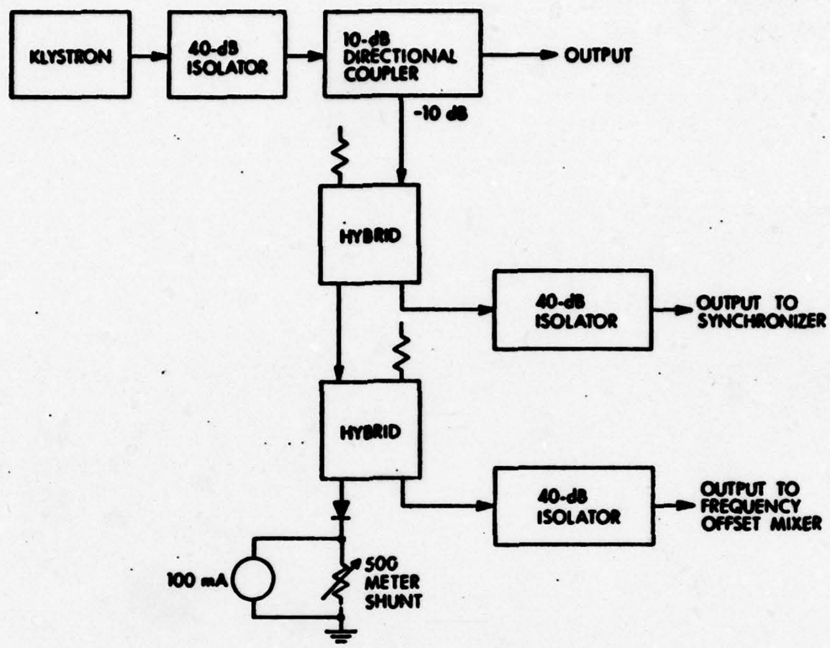


FIGURE 8
KLYSTRON SOURCE BLOCK DIAGRAM (U)

DRL - UT
DWG AE-66-183
DWC - RFO
10 - 25 - 66

The C- and X-band klystron source schematic is shown in Fig. 9. The C- and X-band klystrons are mounted on one chassis, each buffered by a 40 dB isolator. The desired klystron is selected by a front panel switch which operates a solenoid microwave switch and also switches supply voltages between the two tubes. Turns-counting dials indicate manual tuning point. A level control is available on the front panel along with a meter to indicate relative power. A leveling circuit is installed in the unit which may be used at somewhat reduced power output. A meter on the front panel indicates relative power.

B. Synchronizing System

The synchronizing system is shown schematically in Fig. 10. The grid bracketing pulse was added, the PRF was made variable, and the receiver blanking pulse was made variable from 0 to 15 μsec. A divider by 2 converts 100 kHz from the GR1115B to 50 kHz which is recorded as a frequency reference on one channel of the tape.

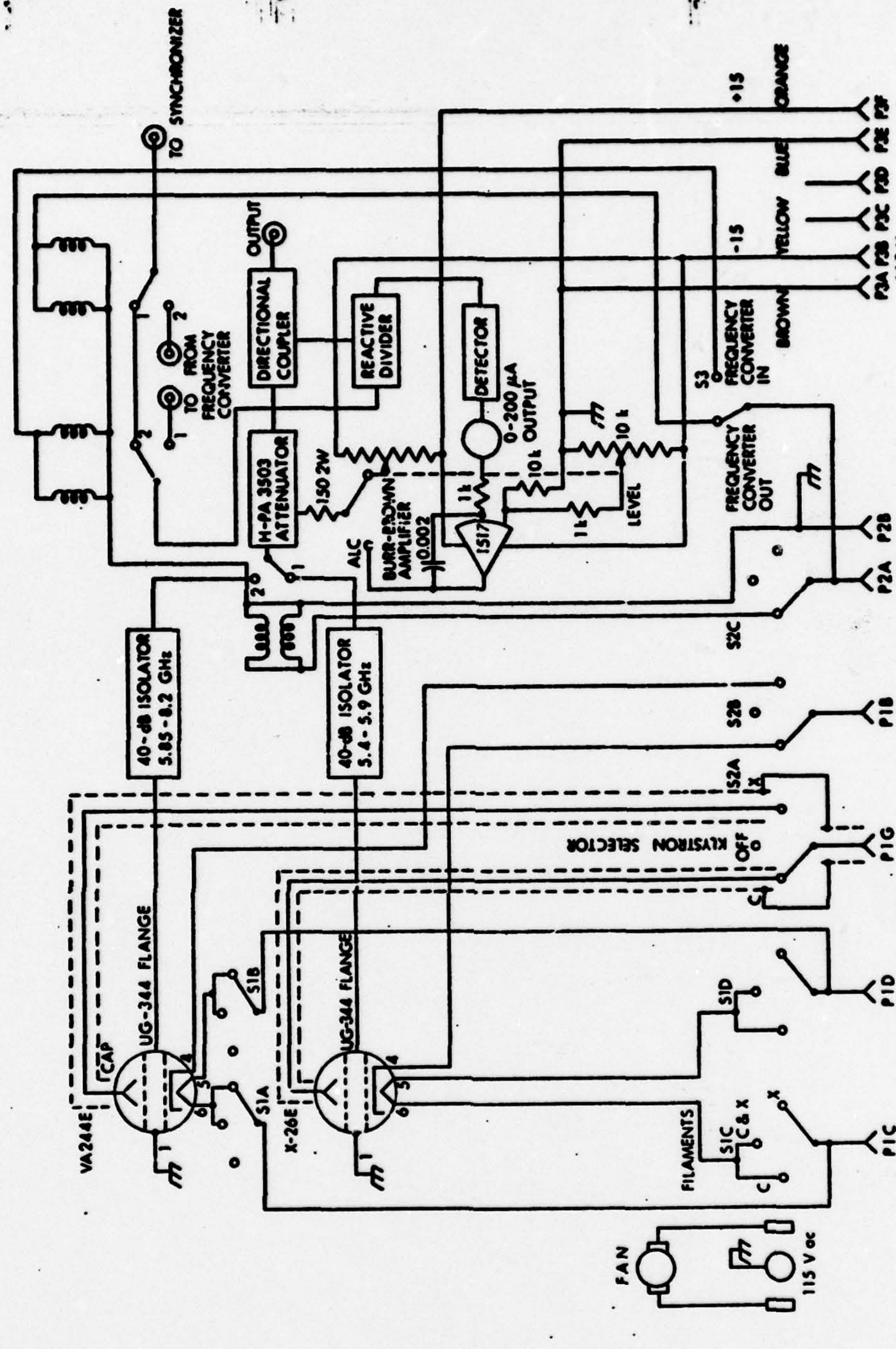


FIGURE 9
C AND X-BAND KLYSTRON SOURCE SCHEMATIC

DRL - UT
DWG AE-66-160
DWC - RFO
8-8-66
REV 1-25-67

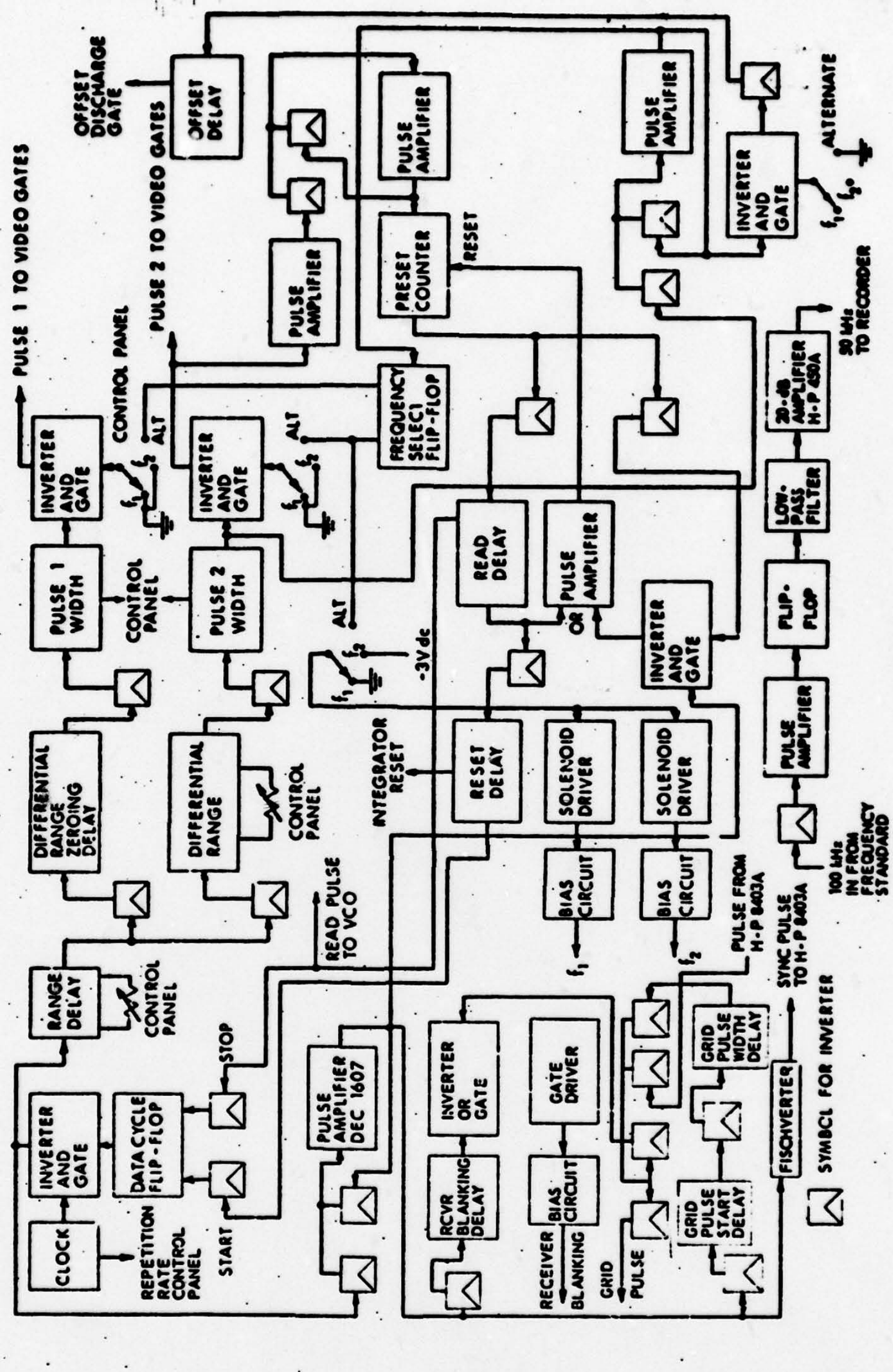


FIGURE 10
SYNCHRONIZING SYSTEM BLOCK DIAGRAM

DRL - UT
DWG AE-65-97
DWC - KLK
7 - 7 - 65
REV 1 - 26 - 67

III. RAIN CLUTTER MEASUREMENTS AT AUSTIN

During the months of May, June, and July the clutter radar was set up to measure rain clutter at the Balcones Research Center. A 22 x 13 ft shelter 10 ft high was erected to shelter the antennas.

Most of the rains observed were fairly localized so that it was necessary to range track the rain manually and to follow the rain in azimuth. It was difficult to obtain much data in this manner because rains are rarely heavy in Austin, and often only one man would arrive at the site in time to get data. Many unsuccessful attempts were made, the rains being too light or of too short duration. The rain clutter measurements were all made with only 20 W of transmitted power, which limited the range.

One heavy rain was observed and data were taken at various ranges. Differential range data were taken at 0.1, 0.3, 1, 3 and 10 μsec pulses with 0, 50, 80, 100, 120, 150, 200 and 300 percent range differential between alternate pulses. Differential frequency data were taken at each of the above pulse widths with frequency separations of 0.3, 1 and 2 or 3 times the inverse of the pulse width.

Data on other occasions usually included differential range data at one or two pulse widths as well as two or three differential frequencies at each pulse width used.

IV. GALVESTON SHAKEDOWN TRIP

On 19 October 1966 the 1 kW tube was turned on under the careful supervision of Adam Bulharowski of APL. On 20 October the radar was driven to Galveston to determine the system's sensitivity to sea clutter and to determine readiness for a longer field trip. A calibration was made there using a corner reflector at a range delay of 3.9 μsec. The Gulf gave a substantial return out to 0.8 miles, although it was not very rough. Sea clutter data were recorded for various differential range and differential frequency settings.

V. CLUTTER MEASUREMENT PROGRAM AT CAPE COD

A. Transportation

The clutter measurement equipment was transported by rail from Austin to Boston. Two flat cars were used. The two generator trucks and the generator trailer were mounted on one, and the semi-trailer, tractor and station wagon were mounted on the other. The van was mounted on a Hydra-Cushion car to minimize shock to the equipment. No perceptible damage occurred in transit. The equipment was chocked with sections of railroad tie and tied down with one-half in. steel cable. The photographs in Figs. 11 and 12 show the equipment mounted. It was mounted and dismounted by members of the field test section, headed by George Blankenship, using military-approved procedures with some improvements.

B. Setting Up Exercises

The clutter measurement equipment was set up at the GATR site of North Truro Air Force Station, Cape Cod, Massachusetts. Since it was not possible to drive the trucks on the beach it was necessary to set up the bistatic receiving antenna from the top of the hill. A place was dug 50 ft up the side of the hill from the beach. The emplacement was reinforced by several railroad ties, and the mount was slid into place by a steel cable which was played out from a generator truck. A set of pictures in Fig. 13 shows the setting up of the receiver site.

C. Site Geometry and Geography

The clutter site geometry is shown in Fig. 14. The height above mean sea level differed by 14 ft between two charts used.

The geography is shown in Fig. 15. The chart has been marked with lines of constant range delay and with transmitter dial azimuth. When the antennas were restored on 14 December the azimuth settings were changed. This is indicated by two sets of azimuth dials on the chart.

FIGURE 11
CLUTTER MEASUREMENT EQUIPMENT ON FLATCAR

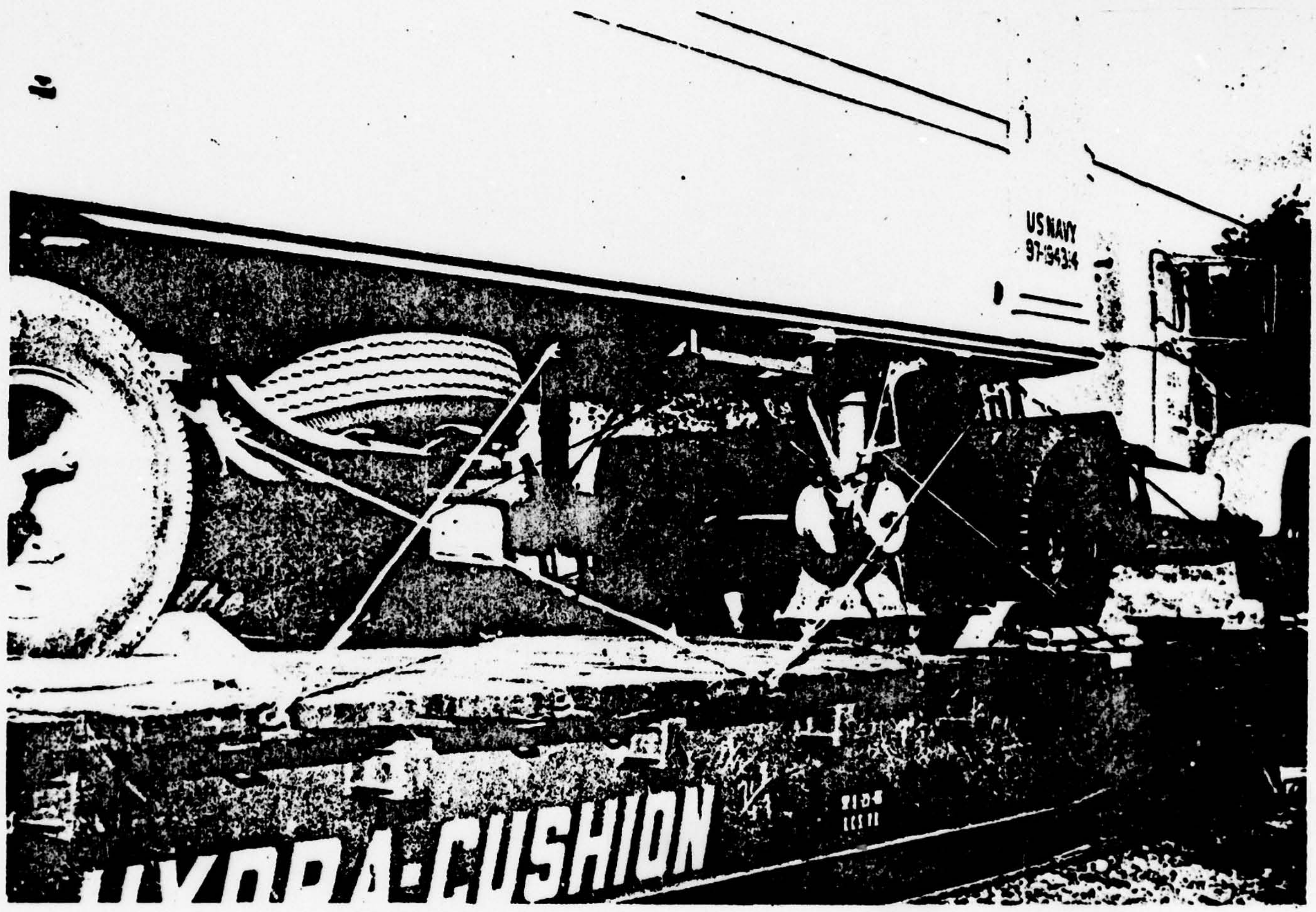


FIGURE 12
CLUTTER MEASUREMENT EQUIPMENT ON FLATCAR

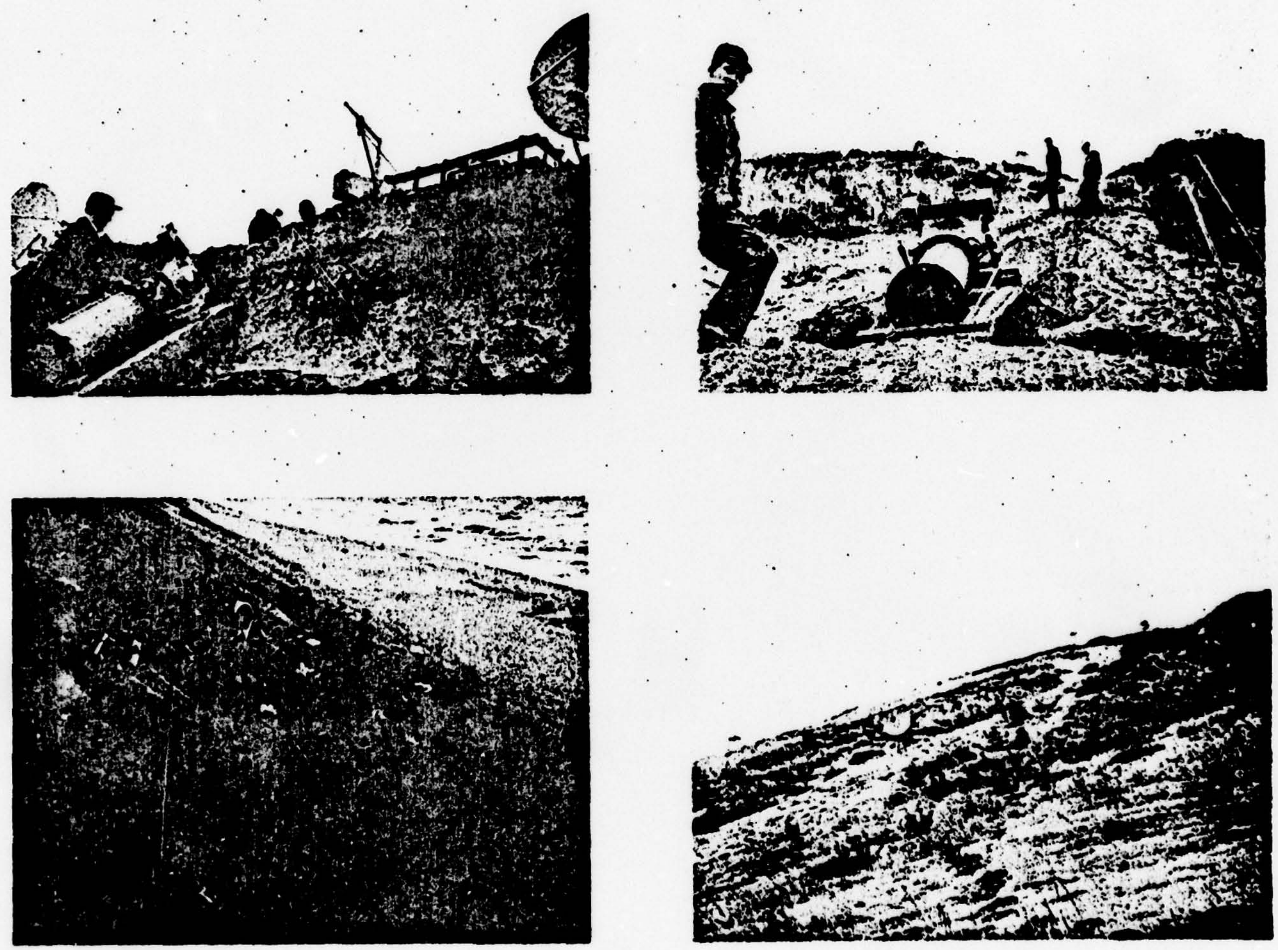


FIGURE 13
SETTING UP RELAY SITE

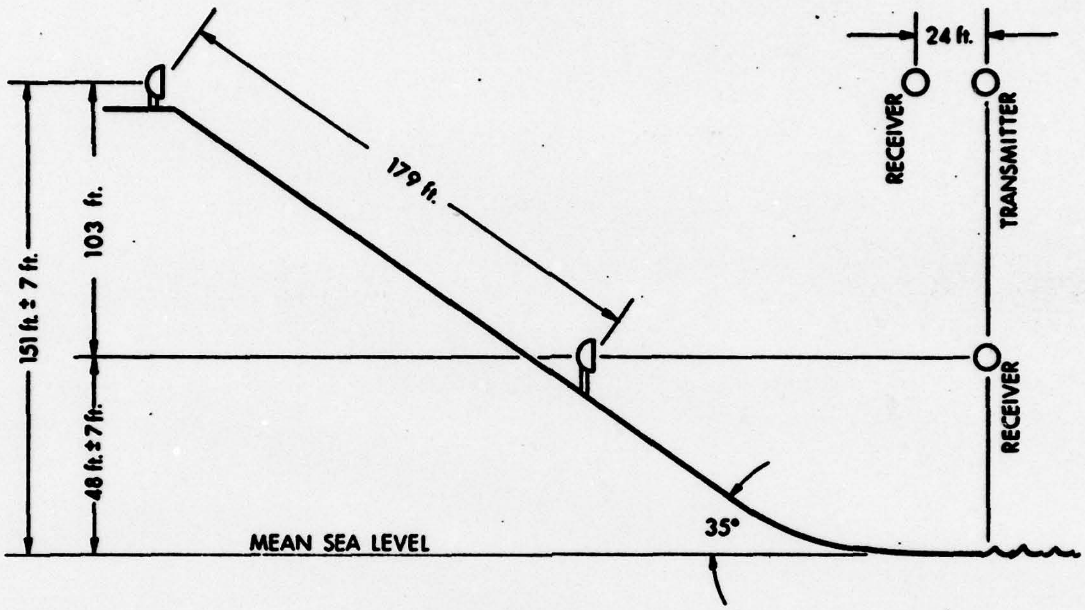


FIGURE 14
SITE GEOMETRY

DRL - UT
DWG AE-67-3
DWC - RFO
1 - 24 - 67

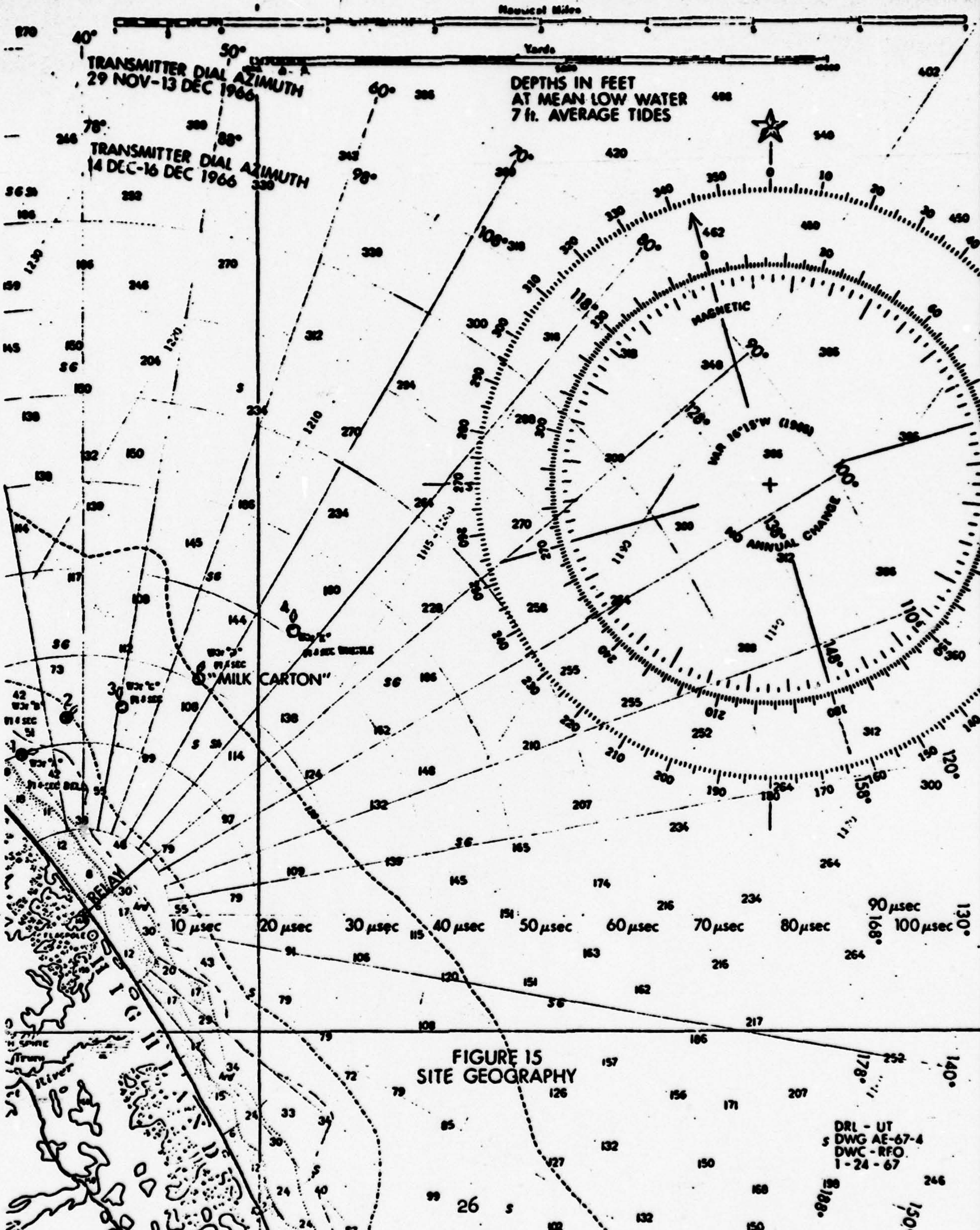


FIGURE 15
SITE GEOGRAPHY

D. Polarization Error

As the polarization of the log periodic antennas is not readily apparent, the two polarizations were incorrectly stated in all of the Cape Cod data. However, the polarization error was consistent and can be corrected by reversing the noted polarization. A photograph showing the antenna in what was called horizontal polarization is shown in Fig. 16. It was taken as a check on polarization and the assumed polarization noted on the back of the photograph. The polarization shown is actually vertical, as indicated in the literature.[4]

E. Clutter Measurement

A seven-track tape recorder, a motor-drive generator, and a time-code generator were loaned by APL for the tests. The time code provides a means of locating data more precisely on the tape. Fifty kHz, derived from the GR1115B 100 kHz output, were recorded on another channel. This, together with the use of the motor-drive generator to stabilize recording speed, should make possible good retrieval of the data. Four general types of radar data were taken. These were differential range, differential frequency, Doppler, and range-tracked waves or swell. The differential range, expressed as parts of a pulse width, is given in Table I for each pulse width used. Table II gives differential frequency expressed as parts of the inverse of the pulse width. Doppler data consisted of 5 single-frequency runs in quarter-quadrants of azimuth at pulse widths of 0.1, 1.0, and 10.0 μsec. Waves or swell were range-tracked by using the A-scope presentation and tracking strong reflections with the range gate. Pulse and gate widths of 0.1 μsec were used. It was possible to track some reflections for one-half mile or more when the sea was rough enough to produce many white caps. (See Appendix B for photographs of the sea.) The technique was used on swells at short range on

[4] Jasik, "Antenna Engineering Handbook," McGraw-Hill Book Co., New York, 1961, p 18-11.

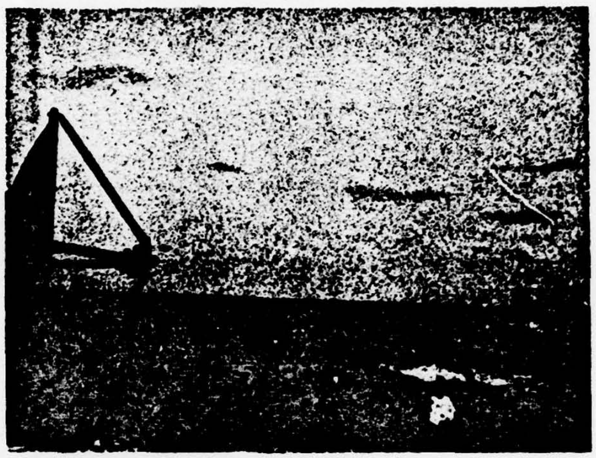


FIGURE 16
ANTENNA

TABLE I

DIFFERENTIAL RANGE

Pulse Width	Differential Range Delay, Parts of Pulse Width								
0.1 μsec	0	1/4	1/2	1	2	4	8	20	
0.3	0	1/6	1/3	2/3	1	2	4	8	20
1.0	0	1/4	1/2	4/5	1	2	4	8	20
3.0	0	1/6	1/3	2/3	1	2	4	8	
10.0	0	1/4	1/2	4/5	1	2	4		

TABLE II

DIFFERENTIAL FREQUENCY

Pulse Width	Differential Frequency, Expressed in Parts of Inverse of Pulse Width					
0.1 μsec	0.01	0.1	0.2	0.5	1	2
0.3	0.015	0.15	0.6	1.5	3	6
1.0	0.01	0.1	0.5	1		20
3.0	0.015	0.15	0.6	1.5	6	60
10.0	0.01	0.1	0.5	1	10	100

10 December. On 12 December an attempt was made to track waves, but there were few white caps, and this probably is related to the lack of trackable waves.[5] Figure 17 shows the A-scope at 3 sec intervals with a 1 μsec/cm sweep. Note that not very many of the reflections can be followed in range. A similar set of photographs was taken on 14 December (Fig. 18) when there were many white caps and many easily tracked reflections. Photographs are also shown for 15 December when it was possible to track the waves very easily (Fig. 19). One set of data was taken on 15 December, at which time the frequency was offset by differing amounts, from 100 kHz to 60 MHz, while tracking the waves.

[5] "Sea Clutter Studies Using Airborne Coherent Radar II," Control Systems Laboratory, Urbana, Ill., 1953.

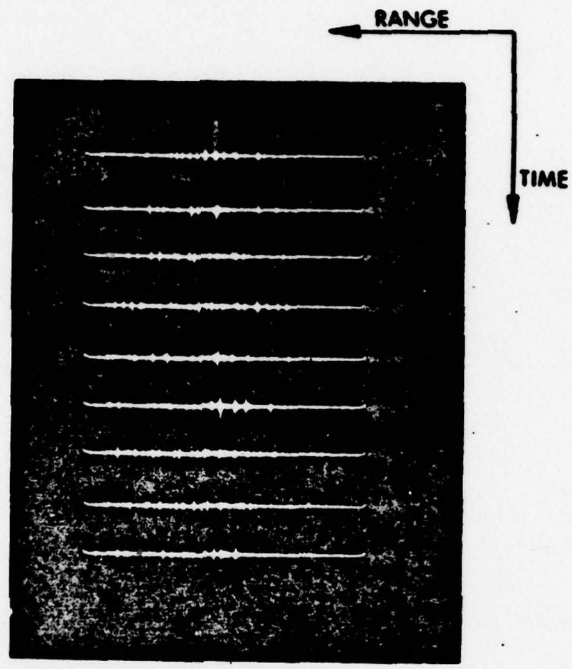


FIGURE 17
A-SCOPE AT 3-sec INTERVALS
0.1-μsec PULSE
12 DECEMBER 1966

DRL - UT
DWG AE-67-5
DWC - RFO
1 - 25 - 67

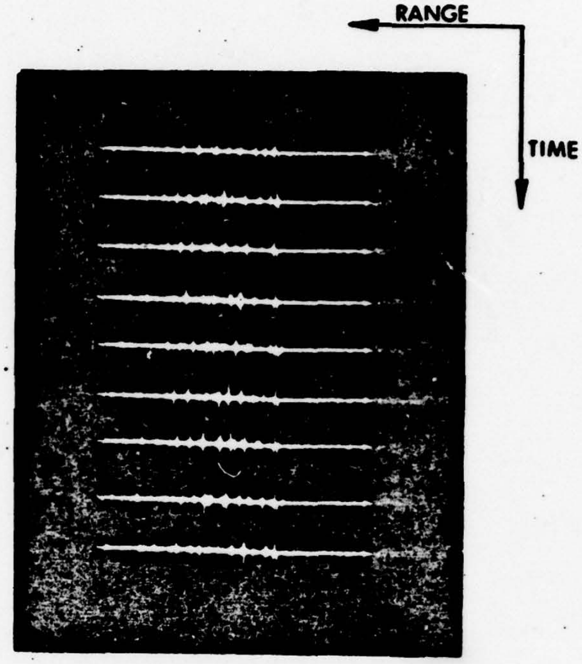


FIGURE 18
A-SCOPE AT 4-sec INTERVALS
0.1-μsec PULSE
14 DECEMBER 1966

DRL - UT
DWG AE-67-6
DWC - RFO
1 - 25 - 67

CONFIDENTIAL

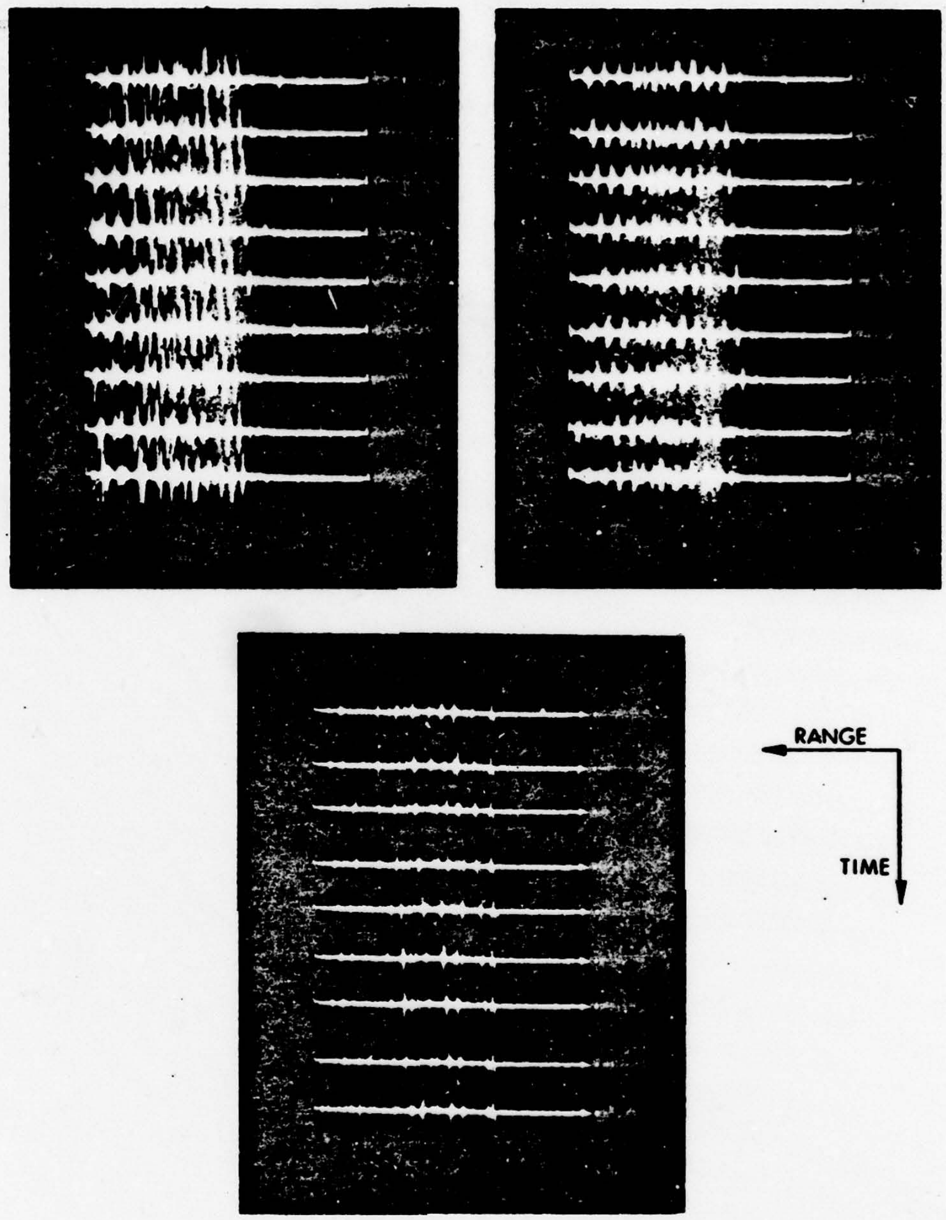


FIGURE 19
A-SCOPE AT 3-sec INTERVALS
0.1-μsec PULSE
15 DECEMBER 1966

DRL - UT
DWG AE-67-7
DWC - RFO
1 - 25 - 67

CONFIDENTIAL

VI. CONCLUSIONS

From limited observations of sea clutter using 0.1 μsec pulses it seems that predominantly area-extensive sea clutter exists only for low sea states, when the width of the pulse is too great to resolve individual reflectors. As the sea state increases the dominant reflectors move apart, and when the sea is rolling enough to produce white caps, individual reflectors are able to maintain their identity as though associated with individual waves. Since the sea is rolling, a sufficiently flat surface is likely to exist, the normal to which bisects the angle between transmitting and receiving antennas. The surface would tend to move continuously with time, unless broken up by turbulence, making it possible to track this flat-plate reflector for several seconds. A calculation shows that a flat plate of 0.1 sq ft would produce a video signal of the magnitude observed.

Some individual reflections in Fig. 18 are approximately 2 V peak-to-peak. This corresponded to roughly 120 dB attenuation between transmitter and receiver. From the radar equation, the attenuation would be the transmitted power divided by the received power, or

$$\text{attenuation} = 10^{12} = \frac{(4\pi)^3 R^4}{G^2 \lambda^2 \sigma}$$

and

$$\sigma = \frac{(4\pi)^3 (3500)^4}{(1600)^2 (0.2)^2 10^{12}} \quad .$$

For a flat plate of area A,

$$\sigma = \frac{4\pi A^2}{\lambda^2} \quad .$$

Substituting,

$$A \cong 0.1 \text{ sq ft} \quad .$$

This type of sea clutter should be correlated for large frequency offsets. One run of differential frequency range-tracked waves was taken in which the frequency offset was made as high as 60 MHz to test this possibility.

In high seas such as those observed at Cape Cod on 13, 14 and 15 December clutter averaging methods would probably not be too effective in suppressing clutter because of the spikiness of the sea return. An alternate method would be to range-track the waves automatically, opening the target gate in synchronism with the passing of a trough.

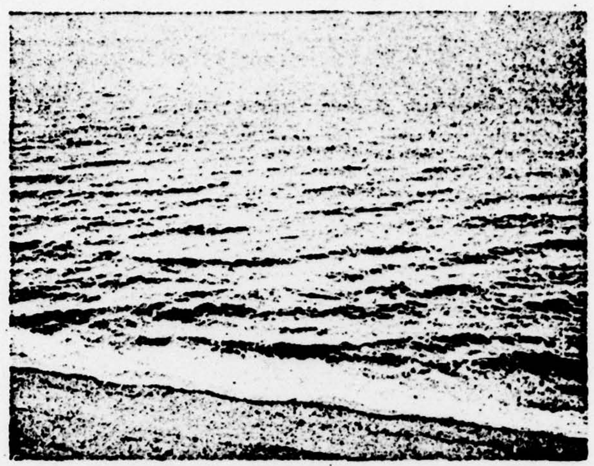
APPENDIX A

Daily Data. Following is a list of the particular types of data taken each day.

Date	Differential Range	Differential Frequency	Doppler	Range Tracking	Polarization (Corrected)	Antenna Separation	Pages in Data Book	Wind Speed and Direction	Wave Height Direction Period	Swell Height Direction	Ripple Direction	Comments
26 Nov	X				H	24'	302-304					
29 Nov	X				H	24'	305-309	2-5 kt 040 deg E		2-3' 105 deg E 12 sec		Swells
1 Dec		X	X		H, V	24'	311-323	12-18 kt ENE	1' N	1' WNW	WNW	See p 314
2 Dec		X			V	24'	324-326	12-18 kt NW	Small NNW	1-2' 7 sec		Light Rain
3 Dec	X	X	X		V	24'	327-339	28-32 kt NNW	1' N	2-3' NNE 5 sec		Occasional Whitecaps
5 Dec			X		V	24'	340-357	10-16 kt WNW	1' NNE 5 sec	E 8 sec	WNW	See p 352
	X				V	24'				1-2'		
6 Dec	X	X	X		H, V	24'	358-386	23-28 kt N	1-2' N	2-3' E 8 sec		Frequent Whitecaps
8 Dec		X			H	100'	388		1-2' SSE 5 sec	1-2' E 7 sec	S	Bistatic Occasional Whitecaps
9 Dec				Swell	H	24'	390					Smooth Sea
10 Dec	X	X		Swell	H	24'	391-400 501-507	10-14 kt W		2-3' E 7 sec		Fog See p 507
12 Dec	X	X	X		H	24'	508-531	7-9 kt NNE	2-3' NE 5 sec			Frequent Whitecaps
13 Dec	X	X			H	24'	532-550	8-10 kt ENE	2-3' ENE 4 sec			Frequent Whitecaps Monostatic and Bistatic
14 Dec	X	X X		Waves Waves	H H	100' 24'	551-567	40 kt ENE	5-6' ENE 6 sec			Bistatic and Monostatic Very Frequent Whitecaps 6 8' Waves Later
15 Dec	X	X		Waves	H, V	24'	568-586	23-27 kt NNE	5-6'			Very Frequent Whitecaps
16 Dec							587-588					Calibration

APPENDIX B

Photos of Sea. Following are Polaroid photographs of the sea from the clutter measurement site.

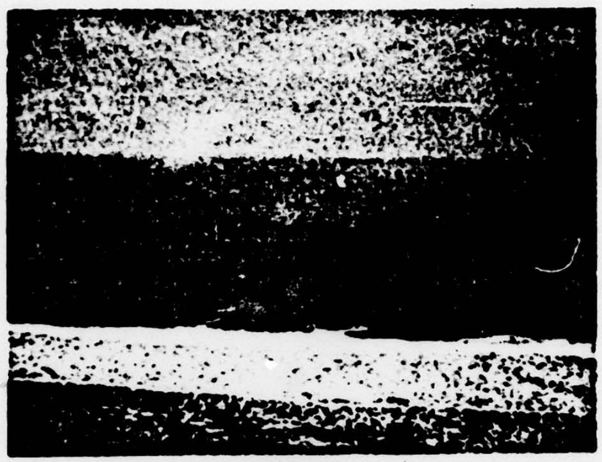


3 DECEMBER 1966
1:45 p.m.

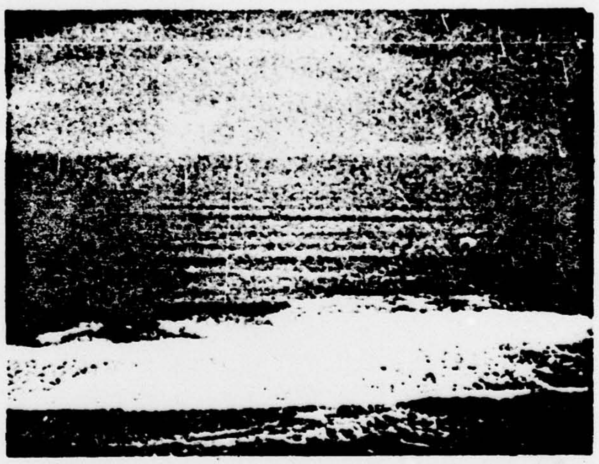
3 DECEMBER 1966
2:10 p.m.

FIGURE 20
PHOTOS OF SEA

181471-57

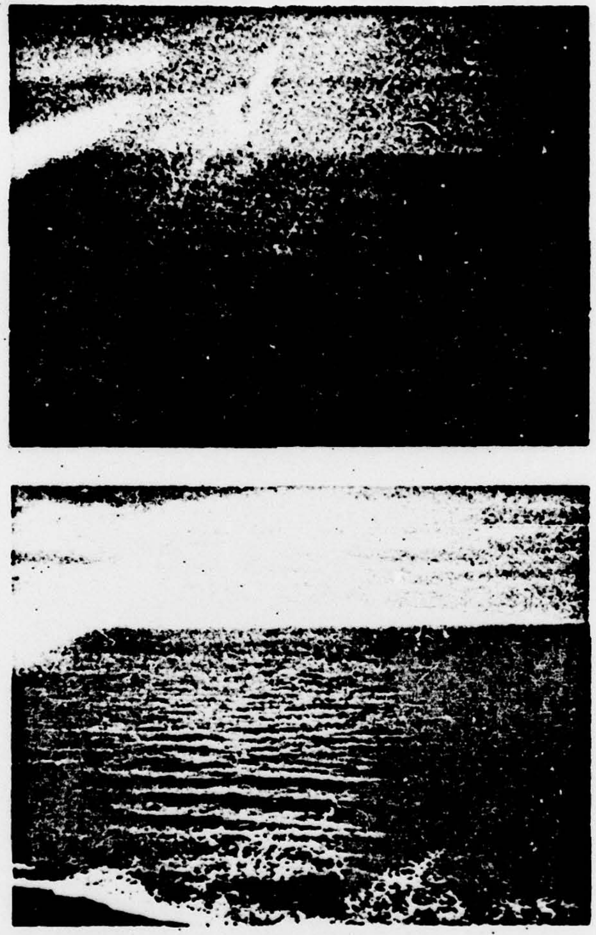


6 DECEMBER 1966
10:20 a.m.



6 DECEMBER 1966
11:55 a.m.

FIGURE 21
PHOTOS OF SEA



8 DECEMBER 1966
10 a.m.
FACING ESE

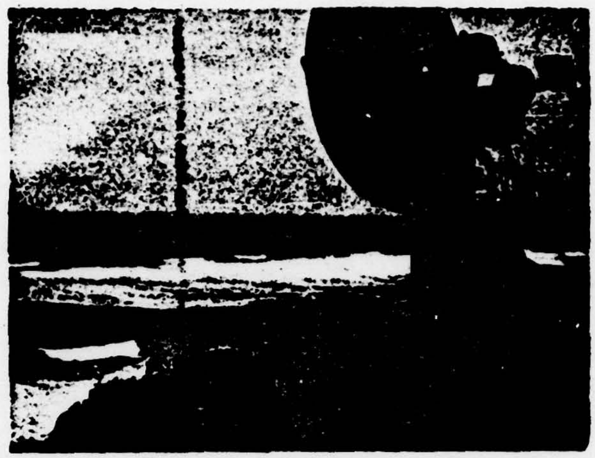
12 DECEMBER 1966
9:50 a.m.
FACING NE

FIGURE 22
PHOTOS OF SEA

13 DECEMBER 1966
10:30 a.m.
FACING E

14 DECEMBER 1966
10 a.m.
FACING ENE

FIGURE 23
PHOTOS OF SEA



15 DECEMBER 1966
9:30 a.m.
FACING ESE

15 DECEMBER 1966
12:05 p.m.
FACING NE

FIGURE 24
PHOTOS OF SEA

CONFIDENTIAL
Security Classification

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) Defense Research Laboratory The University of Texas at Austin Austin, Texas 78712	2a. REPORT SECURITY CLASSIFICATION CONFIDENTIAL 2b. GROUP 4

3. REPORT TITLE

SEA, LAND, AND RAIN CLUTTER MEASUREMENT II (U)

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

DRL Report No. 548

5. AUTHOR(S) (Last name, first name, initial)

Coulbourn, Dixon W.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
9 February 1967	48	---

8a. CONTRACT OR GRANT NO. APL/JHU Subcontract 181471	9a. ORIGINATOR'S REPORT NUMBER(S) DRL-548
b. PROJECT NO. Task G	
c. Authorization Nos. G-3 through G-5	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) ---
d.	

10. AVAILABILITY/LIMITATION NOTICES

Qualified requesters may obtain copies of this report from DDC.

This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
---	Naval Ordnance Systems Command

13. ABSTRACT

A phase-stable pulse radar system with dual frequency and dual range modes of operation was built to study radar clutter. Tests using the radar have resulted in sea and rain clutter data which are being studied by APL/JHU. Instrumentation of the radar was covered in DRL-537 "Sea, Land, and Rain Clutter Measurement" (U) dated 3 May 1966. The present report covers modifications made to the system in 1966. It describes rain clutter measurements made in Austin and sea clutter measurements made in Galveston, Texas, and Cape Cod, Massachusetts. (C)

DD FORM 1 JAN 64 1473 0101-807-6800

CONFIDENTIAL
Security Classification

CONFIDENTIAL (This page is UNCLASSIFIED.)

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Radar Clutter Measurement						
Radar						
Coherent Pulse Radar						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization (*corporate author*) issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, *annual, or final*. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year, or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers (*either by the originator or by the sponsor*), also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through ____________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through ____________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through ____________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring (*paying for*) the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS), (S), (C), or (U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, roles, and weights is optional.

CONFIDENTIAL

Security Classification