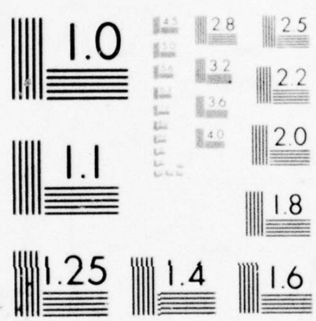
AD-A031 954 GENERAL ELECTRIC CO SYRACUSE N Y HEAVY MILITARY EQUI--ETC F/G 17/1
HIGH LEVEL TRANSMIT-RECEIVE SWITCH SYSTEM. CONFORMAL/PLANAR ARR--ETC(U)
JAN 66 R L ROFINI NOBSR-93022

UNCLASSIFIED NL

1 OF 1
AD
A031954

END
DATE
FILMED
1-77




MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Prepared by
General Electric Company
Heavy Military Electronics Department
Syracuse, New York



Technical Memo

# High Level Transmit-Receive Switch System (U)

## CONFORMAL/PLANAR ARRAY SONAR PROJECT

21 January 1966



Contract NObsr 93022
Project Serial Number SS 048-00
Task 8189
G. E. Requisition Number EH-88157



Prepared for

Navy Department, Bureau of Ships
U. S. Navy Electronics Laboratory
San Diego, California

~~CONFIDENTIAL~~

UNCLASSIFIED

(1) C019-45011

Prepared by

General Electric Company
Heavy Military Electronics Department
Syracuse, New York

(9) Technical Memo.

(6) High Level Transmit-Receive Switch System (U)
CONFORMAL/PLANAR ARRAY SONAR PROJECT.

(12) 52p.

(10) R. L. /Rofini

(11) 21 Jan[redacted]66

(16) SS048

(15)

Contract NObsr-93022

(17) SS04800

Project Serial Number SS 048-00
Task 8189
G. E. Requisition Number EH-88157

Prepared for

Navy Department, Bureau of Ships
U. S. Navy Electronics Laboratory
San Diego, California

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

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

~~GROUP 4~~ = SGDS 6YR1
~~"DOWNGRADED AT 3 YEAR INTERVALS;
DECLASSIFIED AFTER 12 YEARS
DOD DIR 5200.10"~~

UNCLASSIFIED

~~CONFIDENTIAL~~

408 969

# TECHNICAL MEMO

# HIGH LEVEL TRANSMIT-RECEIVE SWITCH SYSTEM

Prepared by

General Electric Company

R. L. Rofini

R. L. Rofini, Responsible Engineer

Approved by

General Electric Company

Lynn R. Zellmer

L. R. Zellmer, Project Engineer

W L Dunkle

W. L. Dunkle, Project Manager

NEL, Code 2110

M. M. Baldwin, Project Technical Director

Letter on file

A

CHANGE SHEET

| CHANGE NUMBER | PAGE NUMBER | EFFECTIVE DATE |
| --- | --- | --- |
| | | |

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Concluded)

ABSTRACT

The objective of this report is to discuss the high-level transmit-receive (TR) switch system and associated problems encountered with a high-power multiple-element sonar system. The results of the investigation of various methods of performing the function of a high-power TR switch are presented and discussed.

Two basic circuits have been considered along with various configurations of these circuits. The most promising appears to be a combination of reed switches and isolating diodes. The final design decision depends on circuit voltages, power levels, and expected usable receiver signal dynamic range.

# SECTION I

# INTRODUCTION

## A. OBJECTIVES

The objective of this report is to discuss the high-level transmit-receive (TR) switch system and associated problems encountered with a high-power multiple-element sonar system. The results of the investigation of various methods of performing the function of a high-power TR switch are presented and discussed.

The functions of a high-level TR switching system are:

1. Connect the transmitter to the transducer and isolate the receiver from the transmitter signal during the transmit interval.
2. Connect the receiver to the transducer and isolate the receiver from the transmitter circuitry during the receive interval.
3. Withstand effects of instances of abnormal conditions such as: (1) the transmit switch opening and closing during the transmit interval, (2) receive switch closing and opening during the transmit cycle, and (3) an underwater explosion initiating abnormal voltages at the transducer input.

## B. BASIC CIRCUITS CONSIDERED

Two basic circuits have been considered along with various configurations of these circuits. These circuits are shown in Figure 1.

The most promising appears to be a combination of reed switches and isolating diodes. The final design decision depends on circuit voltages, power levels, and expected usable receiver signal dynamic range.

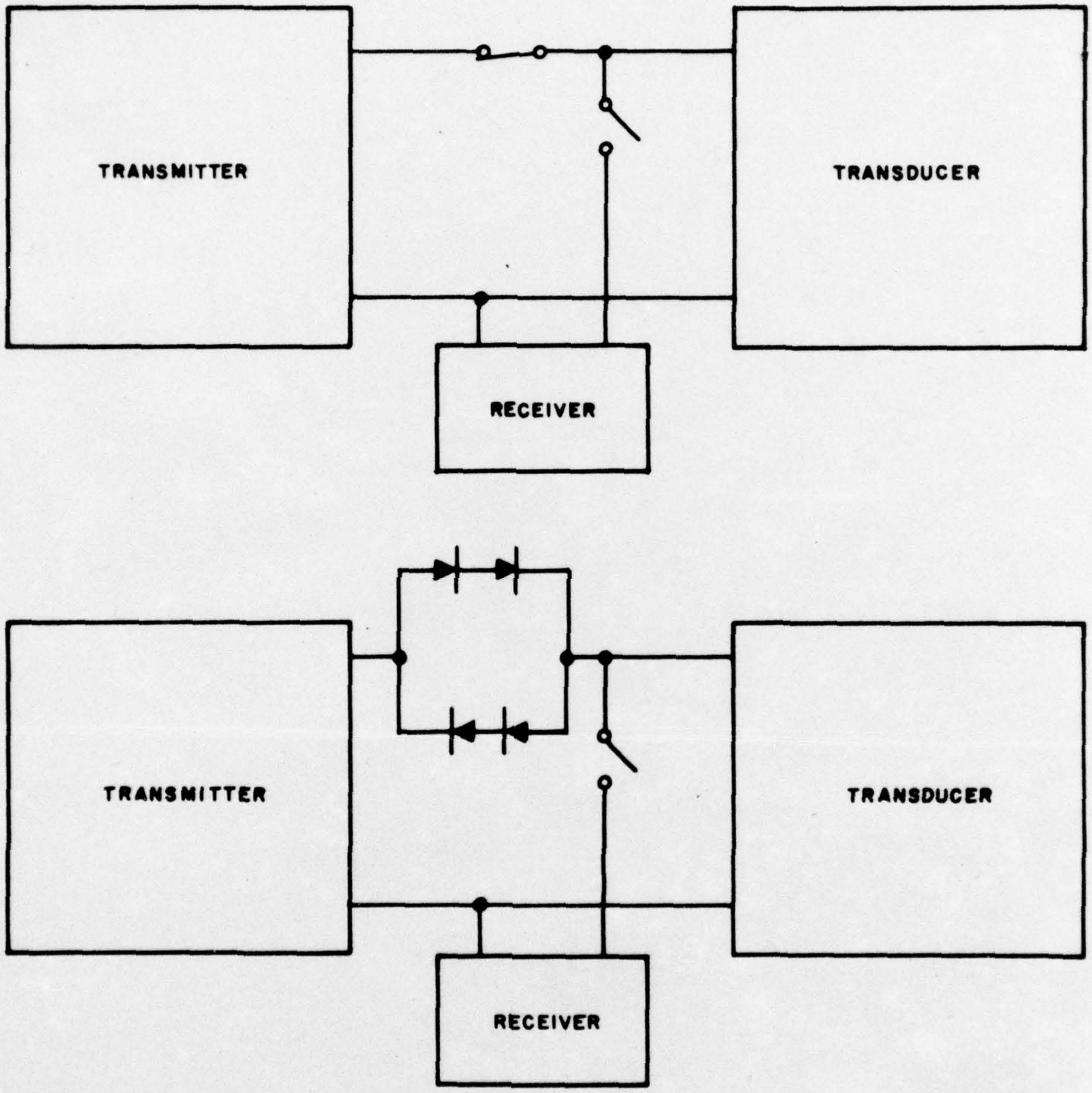



Figure 1. Basic Transmitter-Transducer-Receiver Circuit Interconnections

# SECTION II

# DISCUSSION

## A. TRANSMIT SWITCH

### 1. General Requirements

#### a. Normal Operation

During the transmit interval, the isolating diodes or closed transmit switch must be able to conduct the transmitter current without degradation.

During the receive interval, the isolating diodes or open transmit switch must attenuate the noise existing on the transmitter output so that the noise does not cause unsatisfactory receiver operation. In the case of the isolating diodes, there is an added requirement that the series circuit of the isolating diodes and the transmitter do not attenuate the transducer output signal.

A reasonable operating life should be $2 \times 10^6$ cycles minimum. This is based on the SQS-26 TR switch life requirements.

Based on a 12-second pulse and 25 percent duty cycle, this would amount to a life of about three years.

#### b. Abnormal Operation

A system interlock circuit must be provided that would prevent the transmitter from operating unless the transmit switch is closed. Such an interlock circuit may not be a positive mechanical type (a positive mechanical type being an interlock that is physically closed by the transmit switch). This type of interlock circuit for a relay type transmit switch will monitor coil current to the transmit relay switches. An inadvertent failure in this interlock circuit can bring about an abnormal condition where the transmit switch is opening and closing the transmit circuit. The transmit current can either be the normal transmit current or, in the worst case, the short-circuit current output of the transmitter. Therefore, the ability of the transmit switch to withstand this abnormal condition should be known.

Reed relays usually have a resonant frequency point. Vibration at this resonant frequency may give false operation (depending on peak acceleration) in that contacts that are closed will open for a short period of time. The same situation exists for a set of contacts that are open. Thus, this vibration condition can also bring about the abnormal condition of the relay contacts opening and closing the transmit current (normal or short-circuit) depending on the system's vibration specifications.

A transmit switch opening and closing during the transmit interval makes it necessary to compare the open-circuit voltage output of the transmitter and the dielectric strength of the open transmit switch contacts.

In the case of isolating diodes, it must have the ability to withstand the transmitter short-circuit current output.

Underwater explosions can cause transient voltages to appear across the transducer input. This condition will subject the transmit switch or isolating diodes to transient voltages and currents. The ability of the switch or diodes to withstand these voltages and currents must be known.

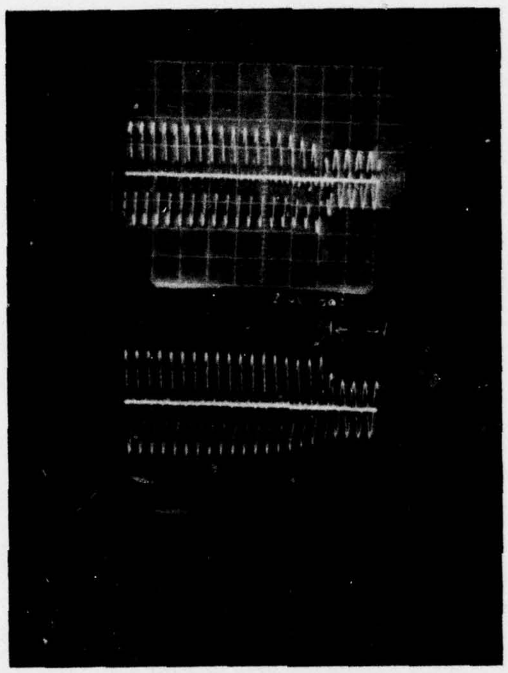
2. Measured Data-Constant Force 640-Watt Transmitter

The following discussion pertains to a Planar Array Sonar System (PASS) where the transmitter output is a constant voltage magnitude and phased current. This type of transducer drive is not necessarily the final design as other types of drive are now being considered. They are (1) constant current magnitude, phased current and (2) constant voltage magnitude, phased voltage. These alternate types of drives impose a change of the operating conditions on the TR switch. When the final type of transmitter driver is determined, the correlation between the results of this study and the operating characteristics of the transducer-transmitter can be made.

The transmit switch or isolating diodes must be able to carry the transmitter output current. The rated constant force transmitter output is 640 watts into a 100-ohm load. This represents a maximum current of 2.53 amps rms during the pulse at a frequency of 2 to 3 kc with a duty cycle of 25 percent and a maximum pulse width of 12 seconds.

a. Short-Circuit Current

The short-circuit current magnitude will be less than twice normal. Figure 2 below is an oscillogram of the transmitter current output as the load resistance is changed from 100 ohms to 2 ohms. Two ohms does not represent a short circuit load to the transmitter, but the oscillogram does show that current limitation does exist and that it is reasonable to expect the transmitter to meet a limitation of short-circuit current to less than twice normal.



1.04 AMPS/CM

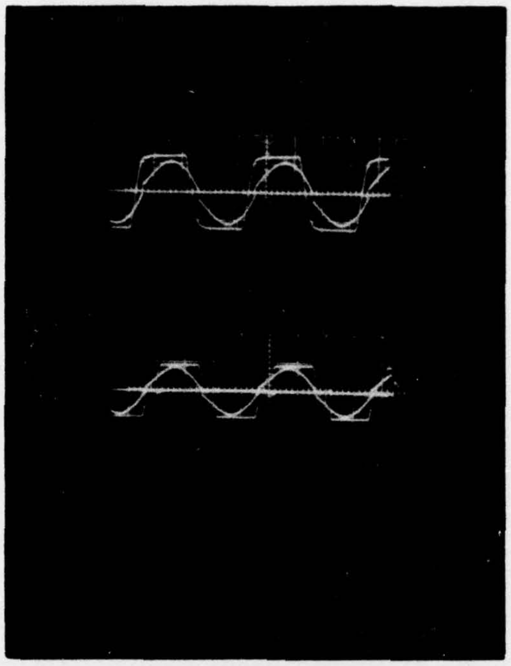
TIME
1000 USEC/CM

Figure 2. Oscillogram Showing Change in Transmitter Output Current as Load is Changed from 100 Ohms to 2 Ohms

b. Open-Circuit Voltage

The open-circuit voltage output of the constant force 640-watt transmitter will be about 1 db of the rated output voltage. The rated output is 253 volts. The peak open circuit voltage will be about 400 volts. Figure 3 below is an oscillogram of the open-circuit voltage and the load voltage for a 100-ohm load.

It is necessary that an open transmit and receive switch be able to withstand this open-circuit voltage.



162 V/CM

405 V/CM

TIME
100 USEC/CM

Figure 3. Oscillogram Showing Normal (100-Ohm Resistance Load) and Open-Circuit Voltage Waveforms

c. Noise

One of the functions of the isolating diodes or a transmit switch is to attenuate the noise existing on the transmitter output. To gain an insight into this area, a test was performed on a transmitter module. The object of the test was to determine the absolute values of voltages and their frequencies at the open-circuit transmitter output with the DC input to the transmitter at its no-load value and a minimum AC driver level. The test circuit is shown in Figure 4.

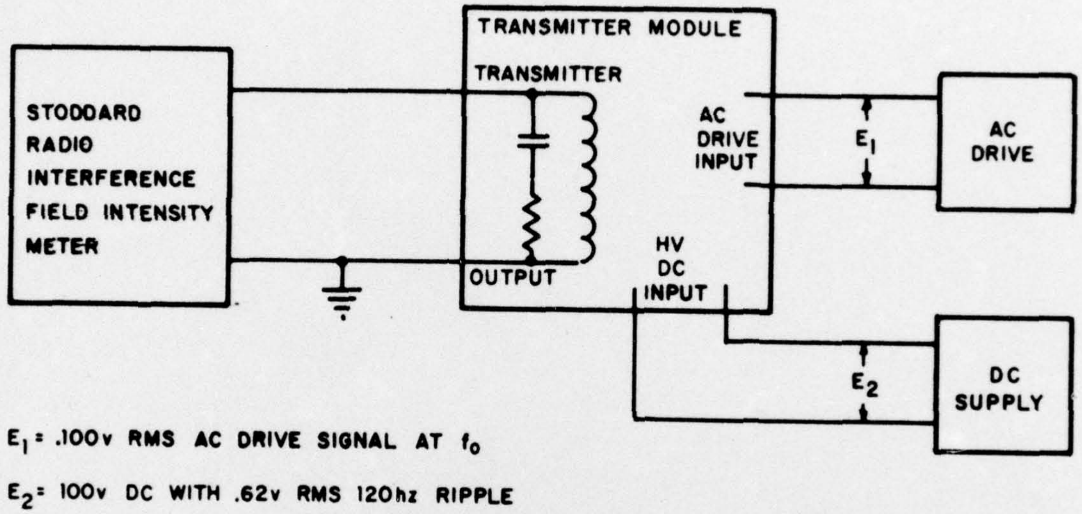



Figure 4. Test Circuit to Determine Transmitter Open-Circuit Output under Minimum AC Voltage

The conditions of the test were similar to what would exist at the transmitter under the receive cycle except for two deviations. These deviations consist of the test circuit having a 0.100-volt rms AC drive at 2.5 KHz. Also, the $E_{dc}$ voltage to the transmitter was 100 volts DC with 0.62-volt rms 120-Hz ripple. The PASS system would have a probable $E_{dc}$ no-load voltage of about 120 volts and an AC ripple frequency of 2400 Hz (400-Hz 3-phase FW rectifier circuit). The 0.100-volt rms AC drive signal at $f_o$ is the probable maximum AC drive permissible during the receive cycle.

The Stoddard Radio Interference Field Intensity Meter is a selective frequency voltmeter with a 6-db bandwidth of 13 to 90 Hz. The voltmeter was tuned from 100 Hz to 12,500 Hz. The results of the test showed:

a. The main noise existing at the transmitter output was 180 microvolts of 120-Hz frequency. It was due to the 120-Hz ripple of the DC supply.

b. The 0.100-volt rms drive signal of 2.5 KHz contributed less than 5 microvolts at its fundamental or harmonic frequencies of 12.5 KHz or less.

c. A VTVM placed on the transmitter output measured 50 microvolts rms. No attempt was made to correlate the 50-microvolt reading by the VTVM with the readings at various frequencies by the Stoddard meter.

The test results show that the noise at the transmitter output will mainly be the transmitter supply ripple frequency.

d. Transmitter Impedance

If isolating diodes are used, the circuit shown in Figure 5 exists during the receive interval.

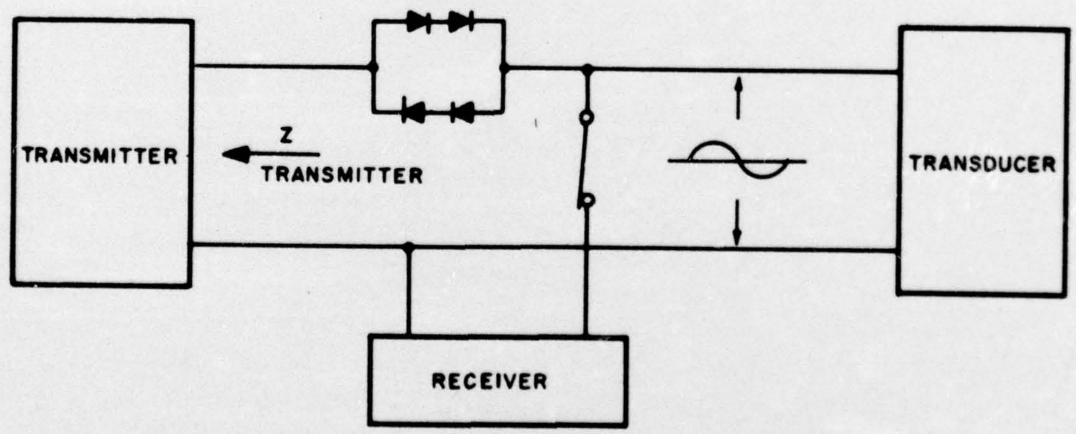



Figure 5. Transmitter, Receiver, Transducer Connection During Receive Interval

The series circuit of the isolating diodes and the transmitter must not attenuate the transducer output signal.

A test of the present 640-watt transmitter to determine $Z_{transmitter}$ was performed. (See Figure 6.)

It shows that with 1 volt 2500 Hz impressed at the transmitter output, $Z_{transmitter}$ is about 1500 ohms. The impedance decreases as the frequency is reduced.

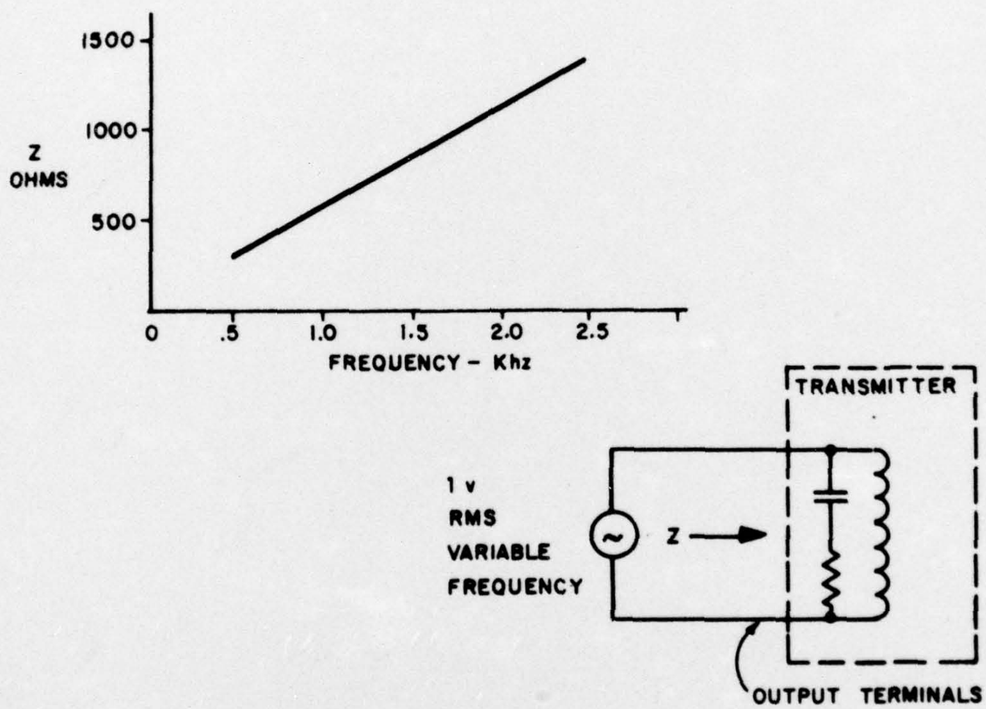



Figure 6. 640-Watt Constant Force-Phased Current Transmitter Output Impedance

e. Transient Voltages

Underwater explosion can cause transient voltages to appear across the output of the transducer. Information in this area is available from test data from the SQS-26 system. Their test circuit is shown in Figure 7 below.

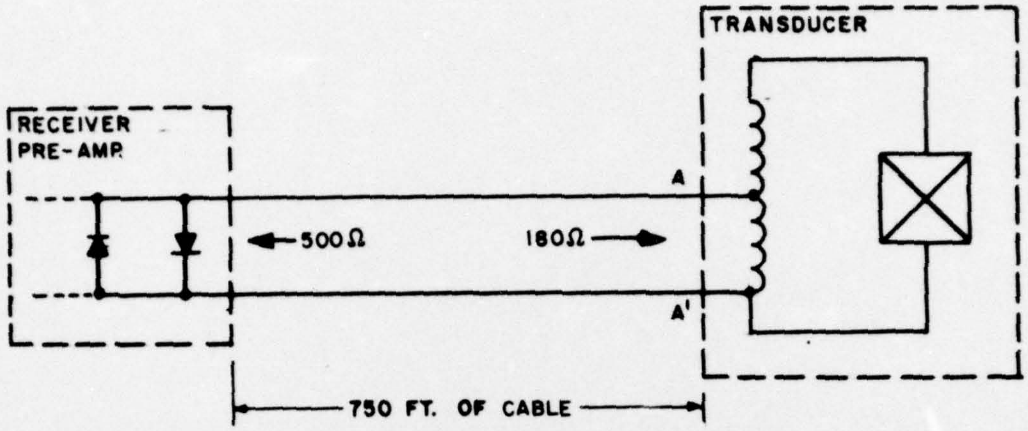



Figure 7. Underwater Explosion Test Circuit

The voltage that appeared at the transducer input A-A' had the shape shown in Figure 8 below.

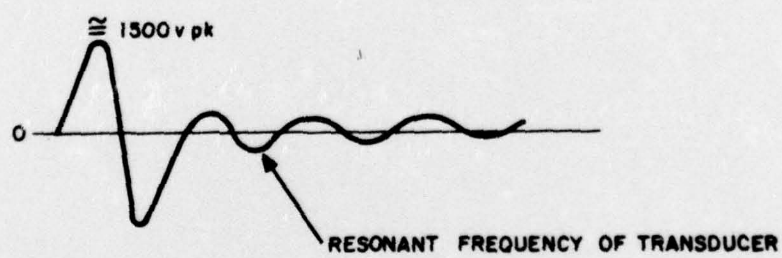



Figure 8. Voltage Waveshape Appearing at Point A-A'

The cable was a DSS-3 type.

Diode junctions (a 1N540 family diode and a base-to-emitter junction of a TO-5 can size transistor) were connected back-to-back across the receiver preamplifier input. The receiver preamplifier was not damaged by the test and performed satisfactorily. The conclusion from the test was that the energy level at the receiver preamplifier was not sufficient to damage the preamplifier.

B. RECEIVE SWITCH

1. General Requirements

a. Normal Operation

During the transmit interval, the receive switch will be open. The open receive switch should provide satisfactory attenuation of the transmitter output voltage so that the voltage to the receiver is not excessive.

During the receive cycle, the receive switch will be closed. It is necessary that the contact resistance of the receive switch be small compared to the receiver input impedance for the expected receiver input current range.

Operating life should be a reasonable number of cycles ($2 \times 10^6$ or greater).

b. Abnormal Operation

During the transmit interval, the receive switch is open. If an open-circuit transmitter load occurs, the open receive switch should provide satisfactory attenuation so that the voltage to the receiver is not excessive.

A system interlock circuit would exist that would prevent the transmitter from operating if the receive switch relay contacts are open. A failure of this interlock circuit could cause the receive switch to close during the transmit interval. Usually, back-to-back diodes are connected across the receiver input to prevent excessive voltages at the input. Therefore, a closed receive switch during the transmit interval presents a short circuit to the transmitter. The receive switch should be able to open and close the transmitter short-circuit current output.

Reed relays usually have a resonant frequency point as described in paragraph A.1.b. of this section. This may cause the receive switch contacts to open and close the transmitter short-circuit current.

Underwater explosions will subject the receive switch to abnormal transient voltages and currents similar to the transmit switch. The ability of the receive switch to withstand this condition should be determined.

2. Receiver Parameters

The required parameters for the receiver have not as yet been completely defined. Consequently, in order to evaluate TR switches, it was necessary to tentatively define these parameters.

The envisioned dynamic range of the receiver will be in the order of 100 db. The anticipated range will fall between 1 microvolt and 0.1 volt and 10 microvolts and 0.1 volt. A minimum signal of one microvolt, though, is not realistic because of minimum noise levels being in the region of several microvolts. Considering an estimated 1000-ohm receiver input impedance and a signal range of 1 microvolt to 1 volt, the receiver input current will fall between $1 \times 10^{-9}$ amps and $1 \times 10^{-3}$ amps.

The receiver listening bandwidth has been tentatively defined as being a minimum of 100 Hz to 3000 Hz.

During the transmit cycle, the receive switch will be open and should provide satisfactory attenuation between the output voltage of the transmitter and the receiver input. The maximum transmitter output will be about 400 volts peak to ground. The maximum receiver input signal will fall between 1 microvolt rms and 1 volt rms. The receiver input will be protected by back-to-back diodes. A receiver switch of 60-db minimum attenuation is reasonable for a receiver impedance of 1000 ohms. This would allow only a 0.40-volt peak signal or less at the receiver under normal operation for all loads.

C. CIRCUITS CONSIDERED

At the beginning of this study program, effort was extended in formulating a complete solid-state TR switch. This effort was discontinued when it was realized that the listening bandpass was going to be at least from 100 Hz to 3000 Hz. These circuits are presented in this report as a matter of record. The transducer is represented by the element's equivalent Van Dyke circuit and the tuning autotransformer.

1. Diodes and Transformer Located Within Transducer

One method involved inserting in the transducer a set of diodes, to conduct during the transmit cycle, and a transformer. Isolating diodes are used as the transmit-switch function. (See Figure 9 below.)

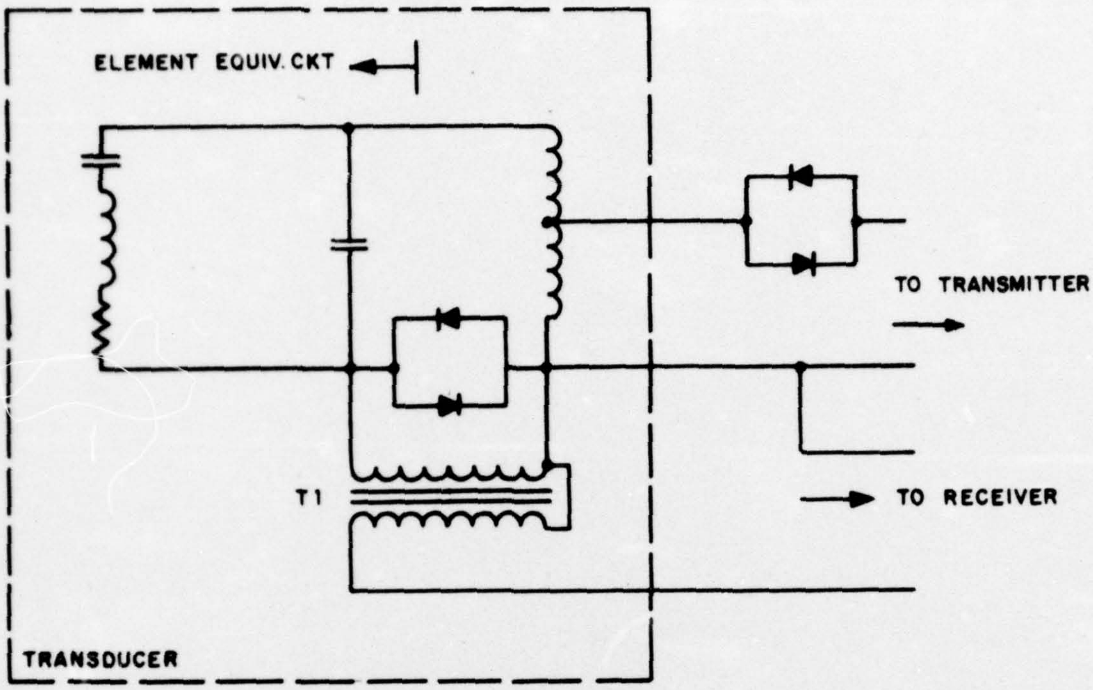



Figure 9. Transducer Circuit Containing Diodes and Transformer

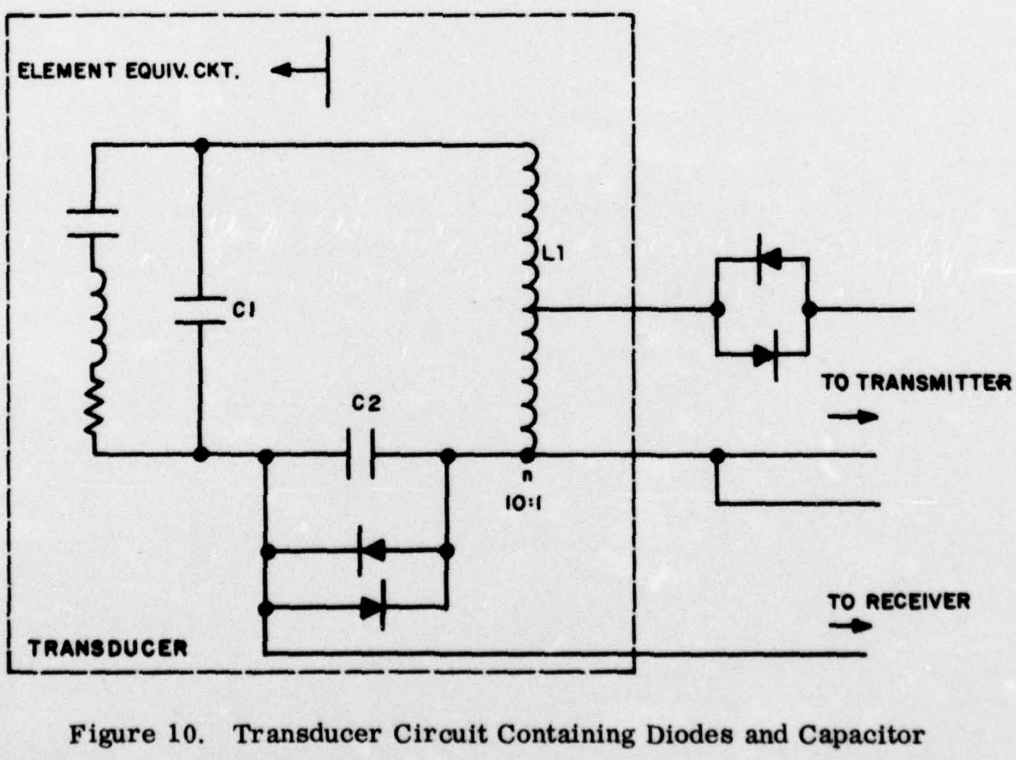



Figure 10. Transducer Circuit Containing Diodes and Capacitor

The disadvantages of this method are the added components in the transducer (transformer T1 could be located in the receiver) and the need for a 3-wire circuit to the transducer. One advantage would be that the common connection of T1 windings could be broken and a balanced input could be presented to the receiver.

2. Diodes and Capacitor Located Within Transducer

Another method involved inserting a capacitor and diodes in the transducer. (Fig. 10)

$C_2 = 10\ C_1$, so that the resonant frequency of $L_1$ and $C_1$ is not effected appreciably by $C_2$. One advantage is that $C_2$ does act as a noise filter at the higher frequencies.

3. Diodes, Inductor, and Capacitor Located Externally to Transducer

The following method (see Figure 11) was evolved in order to reduce the three wires to the transducer to two wires.

The disadvantage is that $C_2$ during transmit is adding capacity to the transducer. The advantage is that it does offer a 2-wire system and does not require any added components to the transducer.

4. Isolating Diodes and Receive Switch with Monitoring Circuits

It may be desirable that the transmitter-transducer-receiver circuit contain circuitry to enable convenient measurement of the transmitter output current and provide a means of inserting a test signal for the receiver.

The following circuit (Figure 12) is one of two circuits that will provide these functions. It contains isolating diodes and a receive switch (reed relay).

The other TR circuit that can be considered is similar to the circuit shown in Figure 12 except that the isolating diodes are replaced by a transmit switch.

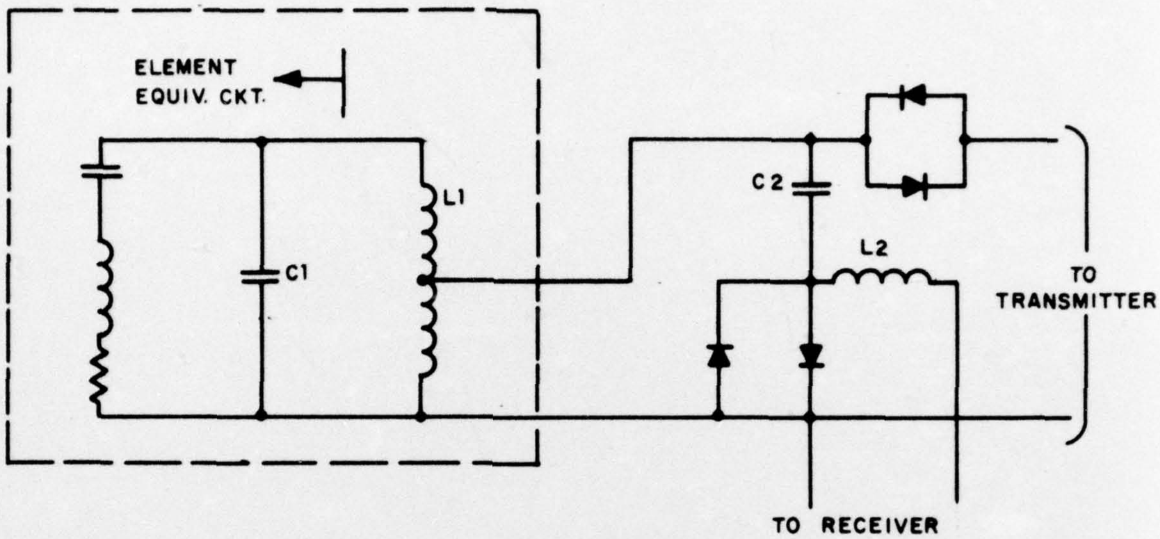
D. COMPONENTS CONSIDERED

The components considered for TR switches were isolating diodes, reed relays, armature relays, vacuum switches, and mechanical switches.

1. Isolating Diodes

Isolating diodes can be used as shown in Figure 12.

The back-to-back connection of the diodes offers a path for the transmit current. During the receive cycle, the receive switch will close. If the voltage that appears across the diode during the receive cycle is less than a few tenths of a volt, the diodes will be a high-impedance circuit. Therefore, the diode's characteristics that dictate its use as a



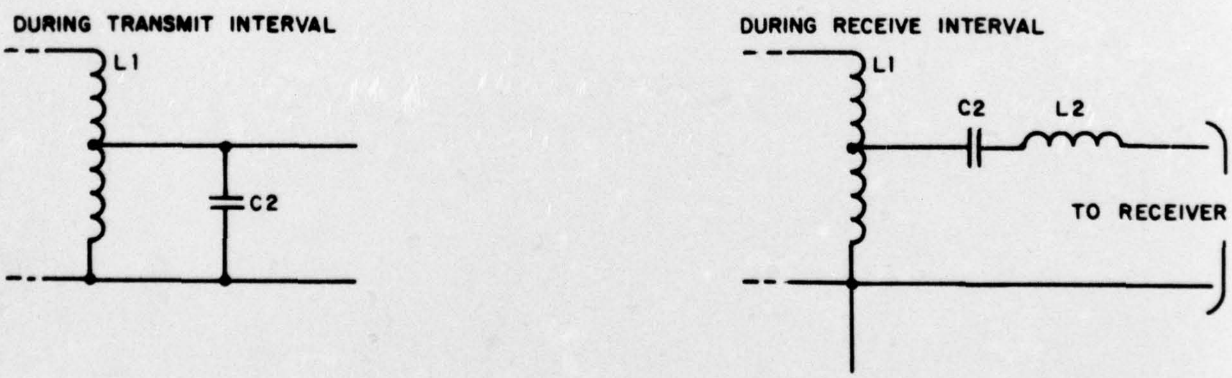




Figure 11. TR Switching Circuit External to Transducer

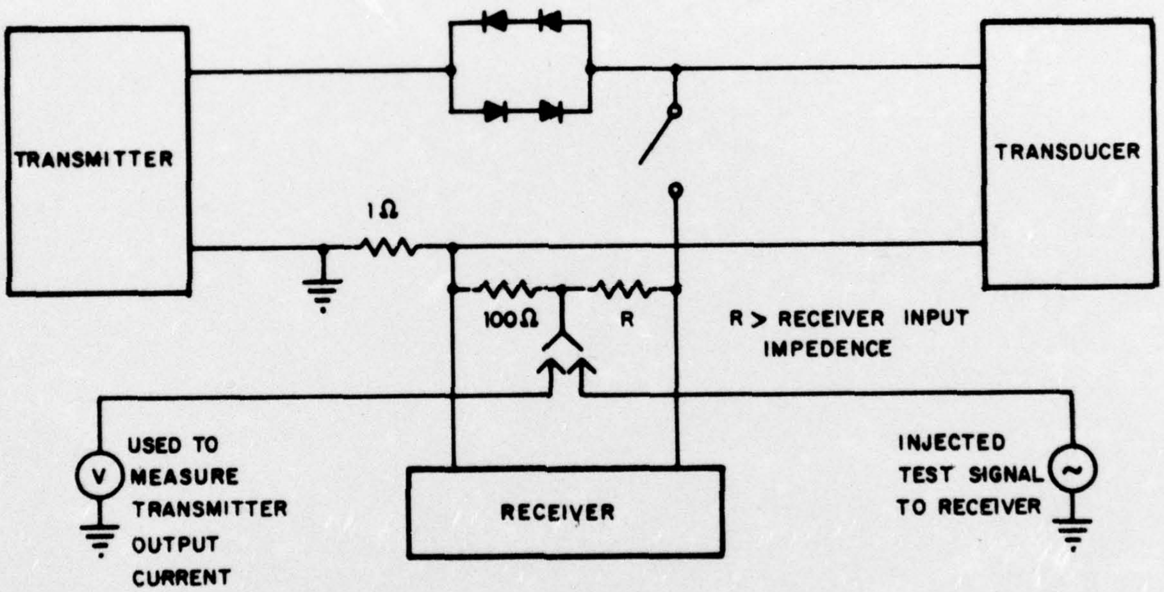



Figure 12. Isolating Diodes and Receive Switch with Monitoring Circuits

TABLE 1

SPECIFICATION OF DIODES TESTED

| Diode | Maximum Current Rating | Peak Inverse Voltage Rating (Volts) | Junction Capacity | Maximum Reverse Current at PIV Voltage | Maximum Forward Voltage Drop | Cost per Diode (Quantities Greater than 1000) |
|---|---|---|---|---|---|---|
| T.I. 1N1128A | Avg rectified fwd current at 50°C stud temp = 3.3 amp at 150°C stud temp = 1.0 amp | 600 | Not Specified | 10 μamp at 25°C amb | 1.1 volts at 1.0 amp D-C at 25°C junction temp | \$4.00 |
| T.I. 1N1124A | Avg rectified fwd current at 50°C stud temp = 3.3 amp at 150°C stud temp = 1.0 amp | 200 | Not Specified | 10 μamp at 25°C amb | 1.1 volts at 1.0 amp D-C at 25°C junction temp | \$1.80 |
| Unitrode UTR62 | Avg fwd current at 25°C amb = 2.0 amps at 100°C amb = 1.0 amp | 600 | Max of 40 pf at 25°C at 0 volt | 5 μamp at 25°C amb 100 μamp at 100°C amb | Specified as min fwd current of 1.0 amp at 1.1 v at 25°C junction temp | \$4.10 |
| Unitrode UTR02 | Avg fwd current at 25°C amb = 2.0 amps at 100°C amb = 1.0 amp | 50 | Max. of 150 pf at 25°C at 0 volt | 5 μamp at 25°C amb 100 μamp at 100°C amb | Specified as min fwd current of 1.0 amp at 1.1 v at 25°C junction temp | \$2.15 |
| Unitrode UTR3360 | Avg fwd current at 25°C amb = 3.0 amps at 100°C amb = 1.5 amps | 600 | Max of 160 pf at 25°C at 0 volt | 5 μamp at 25°C amb 100 μamp at 100°C amb | Specified as min fwd current of 3.0 amps at 1.1 v at 25°C junction temp | \$4.75 |
| N.A.E. 1N1202 | Avg rectified fwd current at 150° stud temp = 12 amps | 200 | Not Specified | Specified as max of 2 ma avg at full load single phase, full cycle avg - 150°C stud temp | Specified as 0.55 v max full load voltage drop single phase, full cycle avg - 150°C stud temp, | \$2.11 |

transmit switch would be its current rating, junction capacitance, resistance in the forward direction, and resistance in the reverse direction.

The diodes tested are shown in Table 1.

a. Transmit Condition

The current rating of the diodes must be such that it is compatible with the transmitter output current under all conditions (normal and short-circuit load). Diode current ratings are well defined in the specifications.

The following oscillograms show typical waveforms of voltages and currents of such a diode transmit switch. One set of oscillograms is for a low power level.

The circuit is shown in Figure 13 below

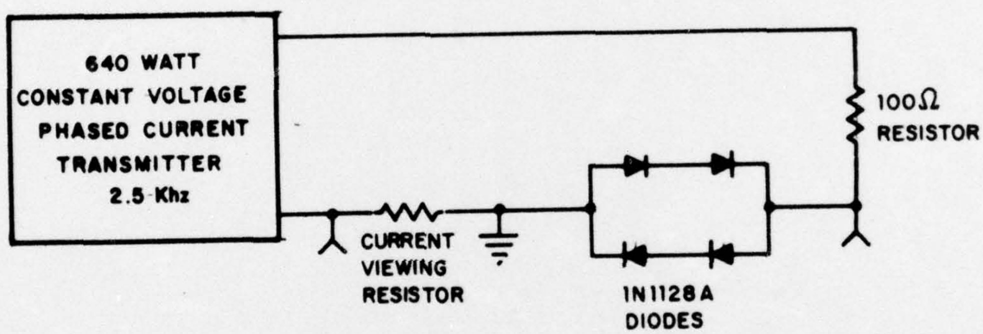



Figure 13. Transmitter, Load, and Diode Transmit Switch Circuit

The open-circuit output voltage of the transmitter will not be detrimental to a diode transmit switch. The only requirement is that the diode assembly be insulated adequately from ground so that the open-circuit voltage does not cause an electrical breakdown.

b. Receive Condition

During the receive cycle it is the diode circuit's function to represent a high impedance circuit between the receiver and the transmitter. The diode's ability to perform this function is dependent on (1) the junction capacity, (2) the diode resistance when forward voltage is applied, and (3) the diode resistance when reverse voltage is applied. The junction capacity parameter is usually given in the specifications for fast-recovery diodes only. The forward voltage-current relationship is usually not given for voltages less than several tenths of a volt. The reverse voltage-current characteristics are also not usually given for voltages less than a few volts. The important point that is being brought out is that the diode parameters that dictate the diode's ability to look like a high impedance are not completely covered in the diode's specification.

Transmitter Output Power = 8 Watts

| | |
|---|---|
| Diode Current and Diode Voltage | 0.26 amps/cm<br>2 v/cm |
| Diode Current | 0.26 amp/cm |
| Diode Voltage | 2 v/cm |
| Load Voltage | 40.5 v/cm |

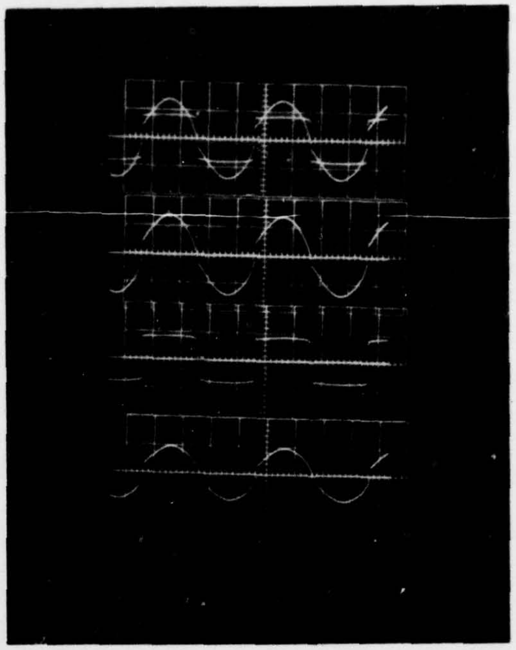


Figure 14. Diode Current and Voltage - Low Power Level

Transmitter Power Output = 580 Watts

| | |
|---|---|
| Diode Current and Diode Voltage | 2.6 amp/cm<br>2 v/cm |
| Diode Current | 2.6 amp/cm |
| Diode Voltage | 2 v/cm |

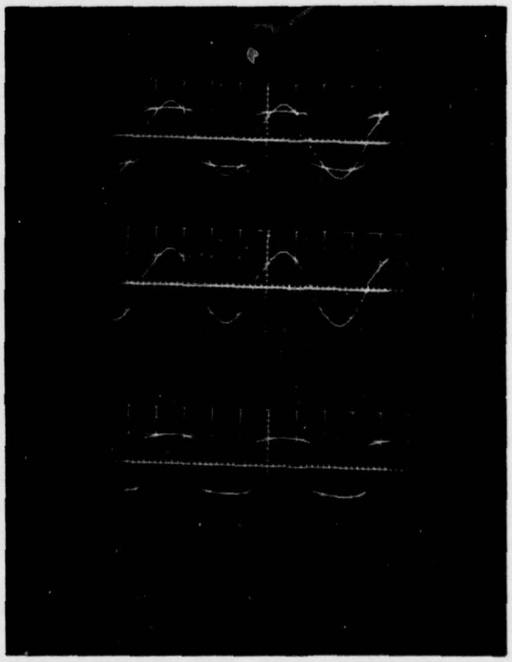


Figure 15. Diode Current and Voltage - High Power Level

(1) Attenuation Characteristics

The first step was to obtain the attenuation characteristics of a diode circuit with a small voltage (less than 0.25 volt) applied across the diodes. The test circuit used is shown in Figure 16 below.

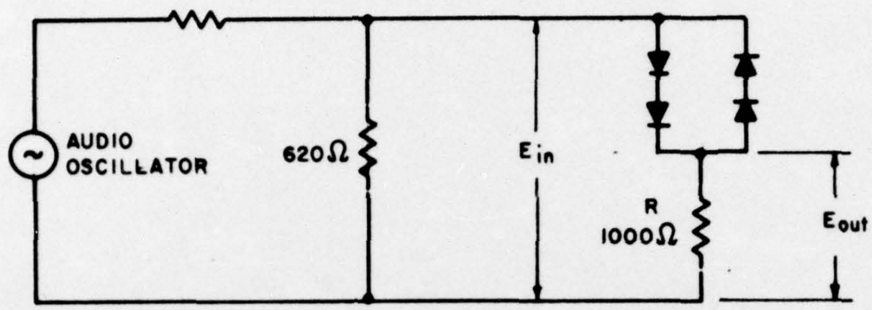



Figure 16. Attenuation Characteristic Test Circuit

The 620-ohm resistor assures $E_{in}$ to be a sine wave voltage even though the diodes are a non-linear impedance. $E_{out}$ was measured by the Stoddard Radio Interference Field Intensity Meter. This meter has a maximum input impedance of 100 kΩ and a capability of measuring voltages of less than one microvolt. It has the advantage of being a selective tuned voltmeter with a 6-db bandwidth of 13 to 90 Hz and a 40-db bandwidth of 60 to 500 Hz. The test was conducted in a shielded room.

The initial test consisted of varying $E_{in}$ and obtaining a calculated value of the diode impedance from the $E_{in}$ and $E_{out}$ measurements. Frequency of the audio oscillator was 3 KHz.The results of the test are shown in Figure 17. The impedance plotted is the calculated impedance from the fundamental voltage readings.

$$(Z \text{ diodes} = \left[E_{in}/E_{out}\right] 1000 \text{ ohms})$$

As the voltage increases past 0.2 volt, the impedance from the fundamental readings begins to drop sharply and the diode impedance starts to become more non-linear. This is shown in the increase of the 2nd and 3rd harmonic components of voltages measured across the 1000 ohms. This is reasonable since we are approaching the low voltage forward drop of the diodes. This is shown in the oscillogram in Figure 18.

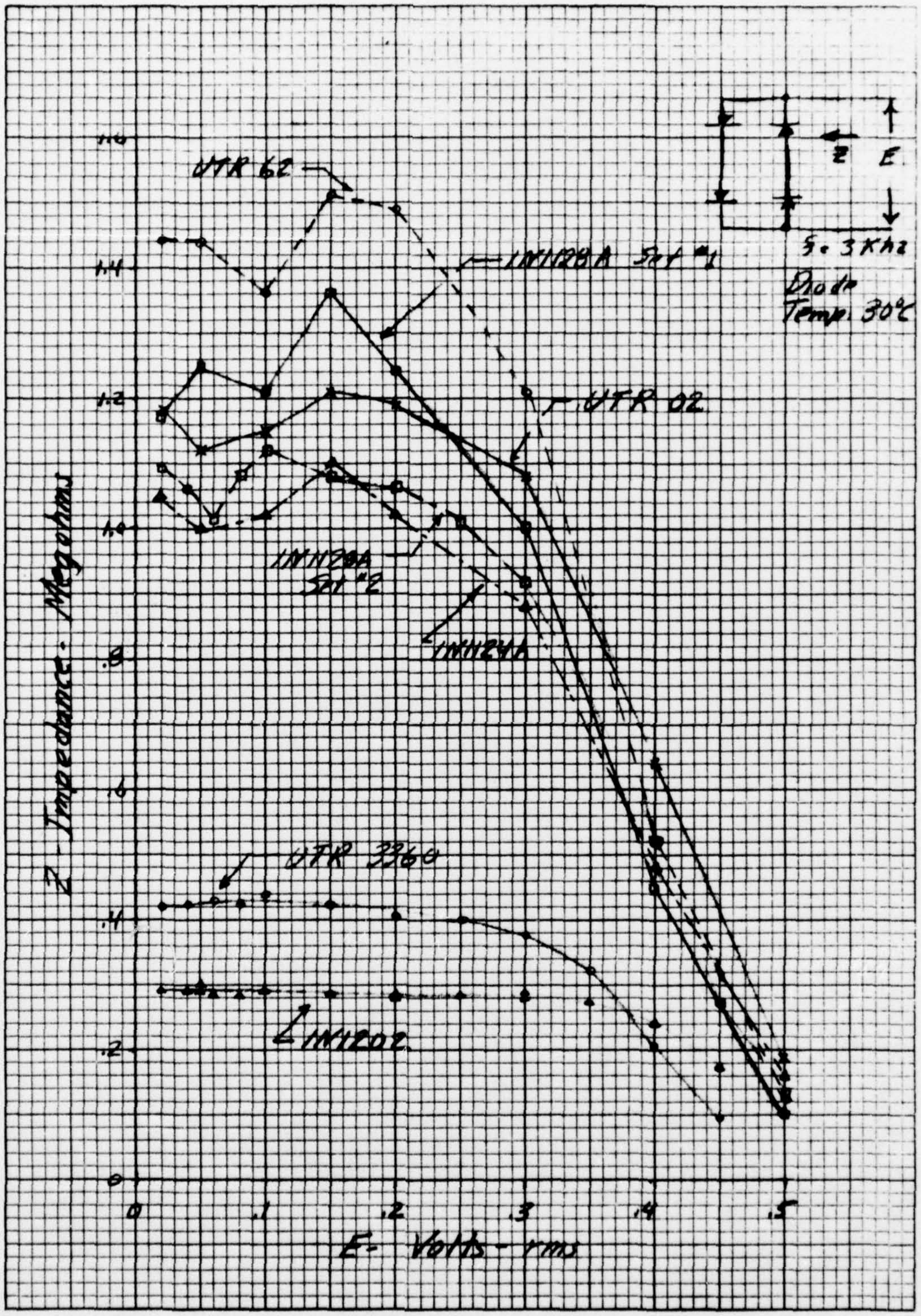
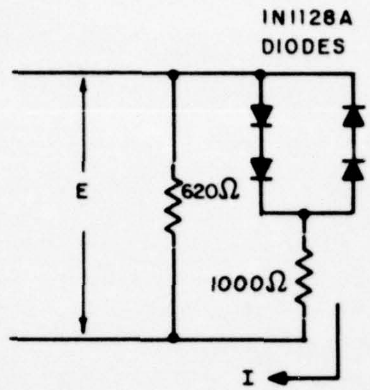
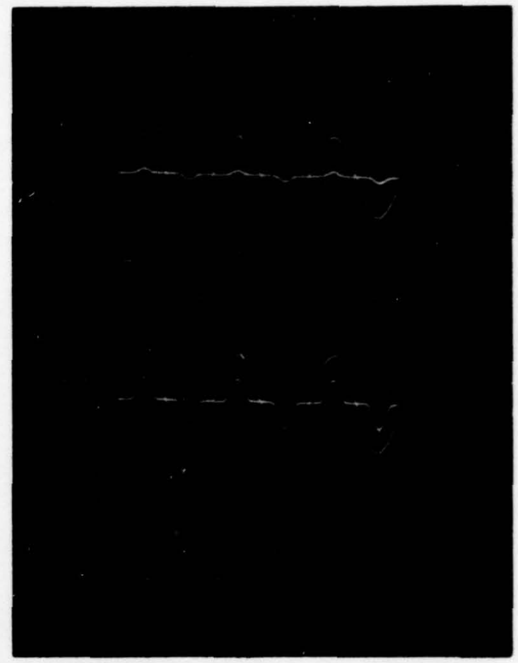



Figure 17. Diode Circuit Impedance versus Voltage - 3KHz



TIME 100 USEC/CM

Figure 18. Diode Circuit Voltage and Current Oscillogram

The following are the fundamental and harmonic voltage readings across the 1000-ohm resistor. These readings are again showing the non-linear impedance of the diode circuit at voltages greater than 0.2 volt.

RMS Microamp Through Diode Circuit

| E | Fund | 2nd Harmonic | | 3rd Harmonic | |
|---|---|---|---|---|---|
| Volts | I | I | % of Fund | I | % of Fund |
| .25 | .25 | .005 | 2.0 | .022 | 8.8 |
| .30 | .33 | .009 | 2.7 | .054 | 16.0 |
| .40 | .78 | .055 | 7.0 | .36 | 46.0 |
| .45 | 1.6 | .11 | 6.9 | .93 | 58.0 |
| .50 | 3.9 | .22 | 5.7 | 2.2 | 56.0 |

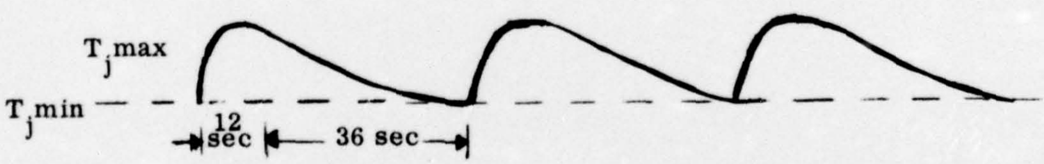
(2) Temperature Characteristics

The next area investigated was the effect of temperature upon the impedance characteristics of the diode circuit. A higher ambient temperature will cause a reduction of the impedance as the reverse leakage current at a given PIV increases with temperature and, for a given forward current, the forward voltage drop of the diode decreases. A circuit of 1N1128A diodes was inserted in a temperature box, and the impedance of the diode circuit was obtained at several ambient temperatures. The results of the test are shown in Figure 19.

The reduction of the diode circuit impedance, as the junction temperature increases, is an important characteristic. A transmit current of 2.5 amperes will result in the 1N1128A diode dissipating about 1.2 watts during the transmit pulse. A usual maximum ambient for operating equipment is 45°C. The thermal resistance of the 1N1129A diode junction to stud is 10°C/watt. The diode stud to heat sink thermal resistance will be less than 1°C/watt and an estimated heat sink thermal resistance would be 5°C/watt (free air 50 sq in. of surface area). The heat sink average rise above ambient will only be 1.5°C (1.2 watts x 25 percent duty x 5°C/watt). The diode stud temperature rise about the heat sink will in the order of a 1°C rise.

For a 12-second pulse and a 25-percent duty, the diode junction temperature, as a function of time, will be

Diode Junction Temperature




$T_j$max > 45°C amb + [10°C/watt junction to stud] [1.2 watt]
> 57°C

$T_j$max ≅ 60°C Considering diode stud and heat sink temperature rise

$T_j$min > 45°C amb

$T_j$min > 47°C Considering diode stud and heat sink temperature rise

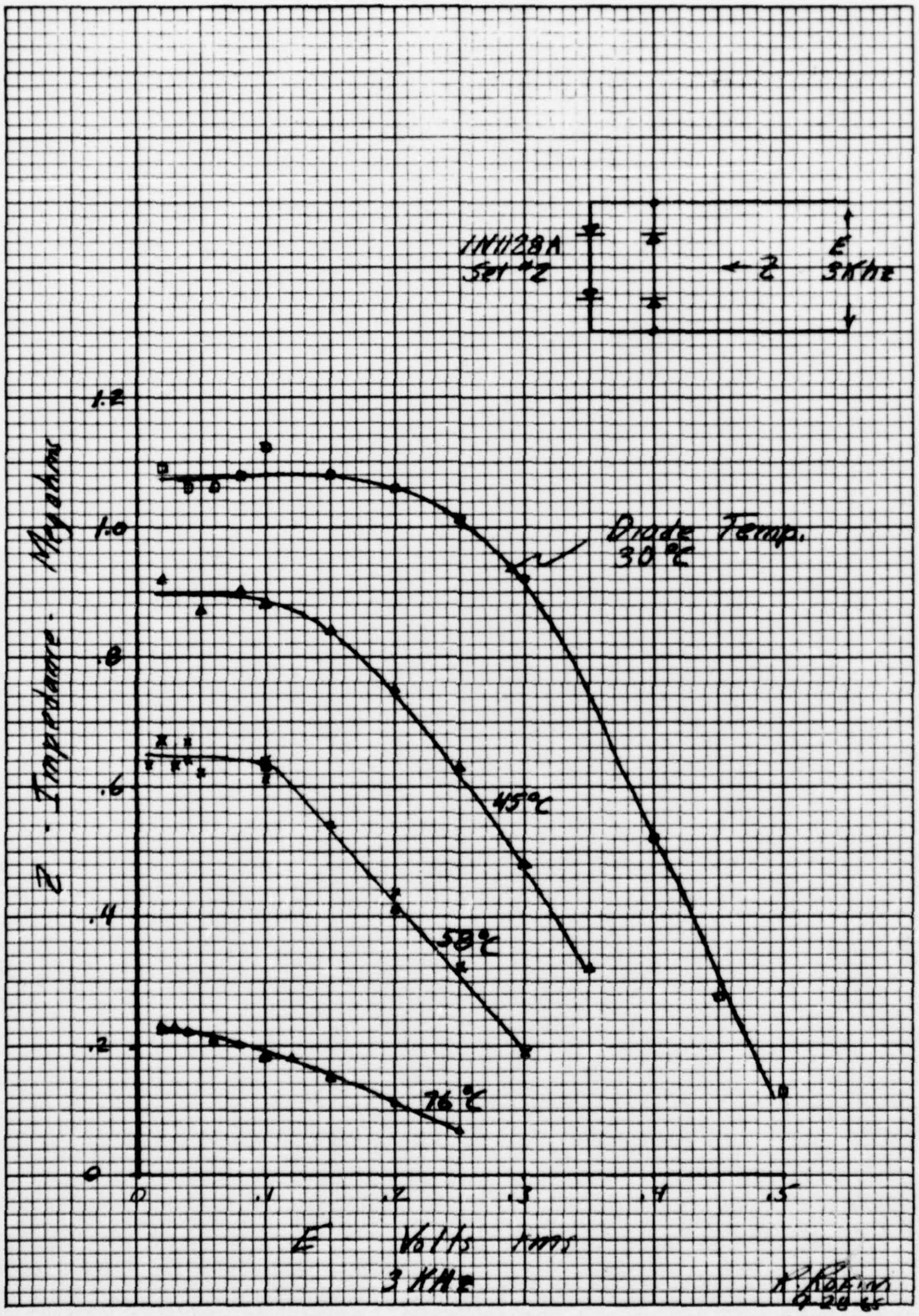



Figure 19. Diode Circuit Impedance at Various Temperatures

Therefore, we can expect the impedance characteristics of the diode circuit to vary from 0.6 megohm to 0.9 megohm during the receive interval. Whether or not 0.6 megohm is a sufficient isolating impedance will be dependent on amount of noise existing on the transmitter output and on the expected dynamic receiver input range and receiver input impedance.

(3) Equivalent Circuit

It would be desirable to obtain an equivalent circuit for a diode circuit. Therefore, a test was performed in which the voltage across the diodes was held a constant value (0.10 volt or less) and the frequency of the audio oscillator was varied. The results of the test are shown in Figures 20, 21, 22, 23, and 24.

The impedance versus frequency curve suggests an RC circuit. The impedance of an approximate RC equivalent circuit is shown also on the curves.

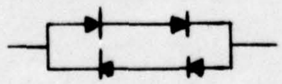
The equivalent capacitance was also measured by a Boonton Type 260A Q meter. The results are tabulated below:

| | Capacitance-picofarad | | | |
|---|---|---|---|---|
| | 29°C | | 45°C | |
| Diode Circuit of | Calculated (From RC Equiv Ckt) | Measured Boonton Meter | Calculated (From RC Equiv Ckt) | Measured Boonton Meter |
| IN 1128A Set #1 | - | 42 | - | - |
| IN 1128A Set #2 | 43.6 | 43 | 51.5 | 49.5 |
| IN 1202 | 174 | 174 | - | - |
| UTR 3360 | 122 | 110 | - | - |

Maximum discrepancy is about 10 percent.

(4) Multiple DIODE Circuits

The majority of the tests conducted were for a diode circuit of four diodes connected



It is possible to use a circuit of only two diodes. As would be expected, resultant impedance is only half of the impedance of the four diode circuits. Test results tabulated below show a comparison of the two and four diode circuits.

The degree of attenuation required by the diode circuit is dependent upon:

(a) <u>The Magnitude of the Transmitter Noise on the Output Circuit.</u> This would not seem to be a serious problem since diode circuits with UTR62 and 1N1128A have satisfactory impedance for voltages less than 0.2 volt, and frequencies less than 3KHz.

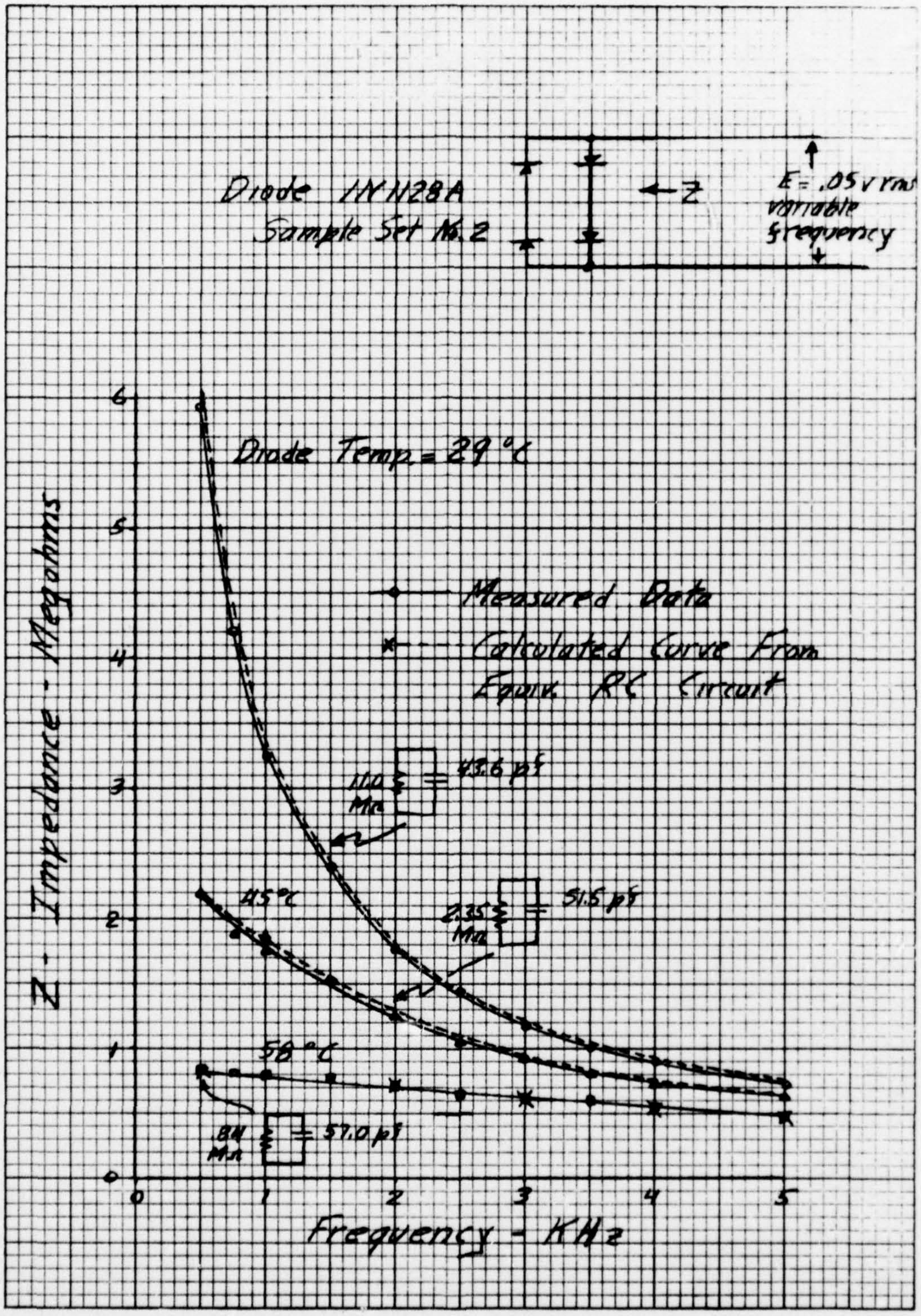



Figure 20. Diode Circuit Impedance versus Frequency

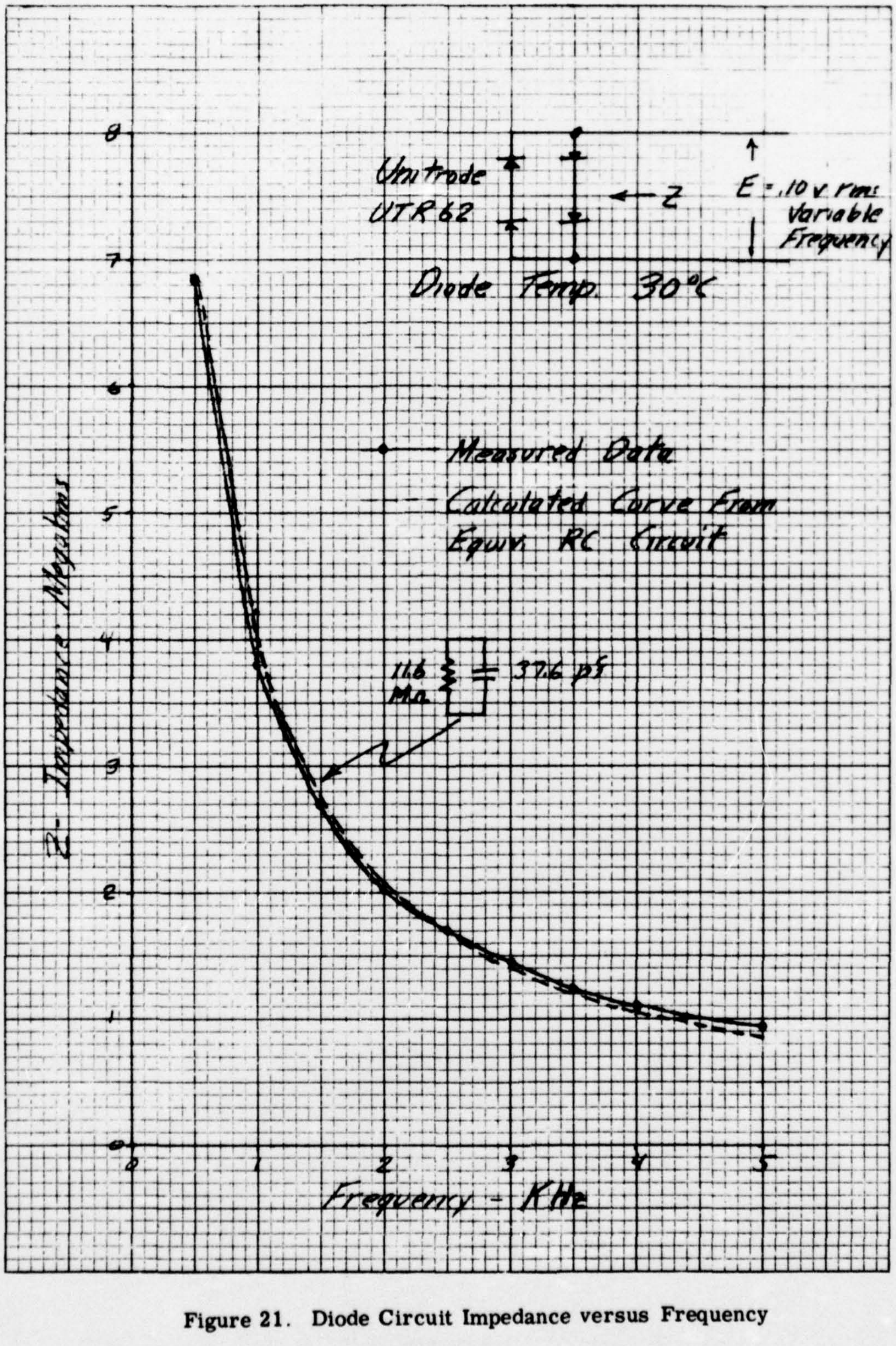



Figure 21. Diode Circuit Impedance versus Frequency

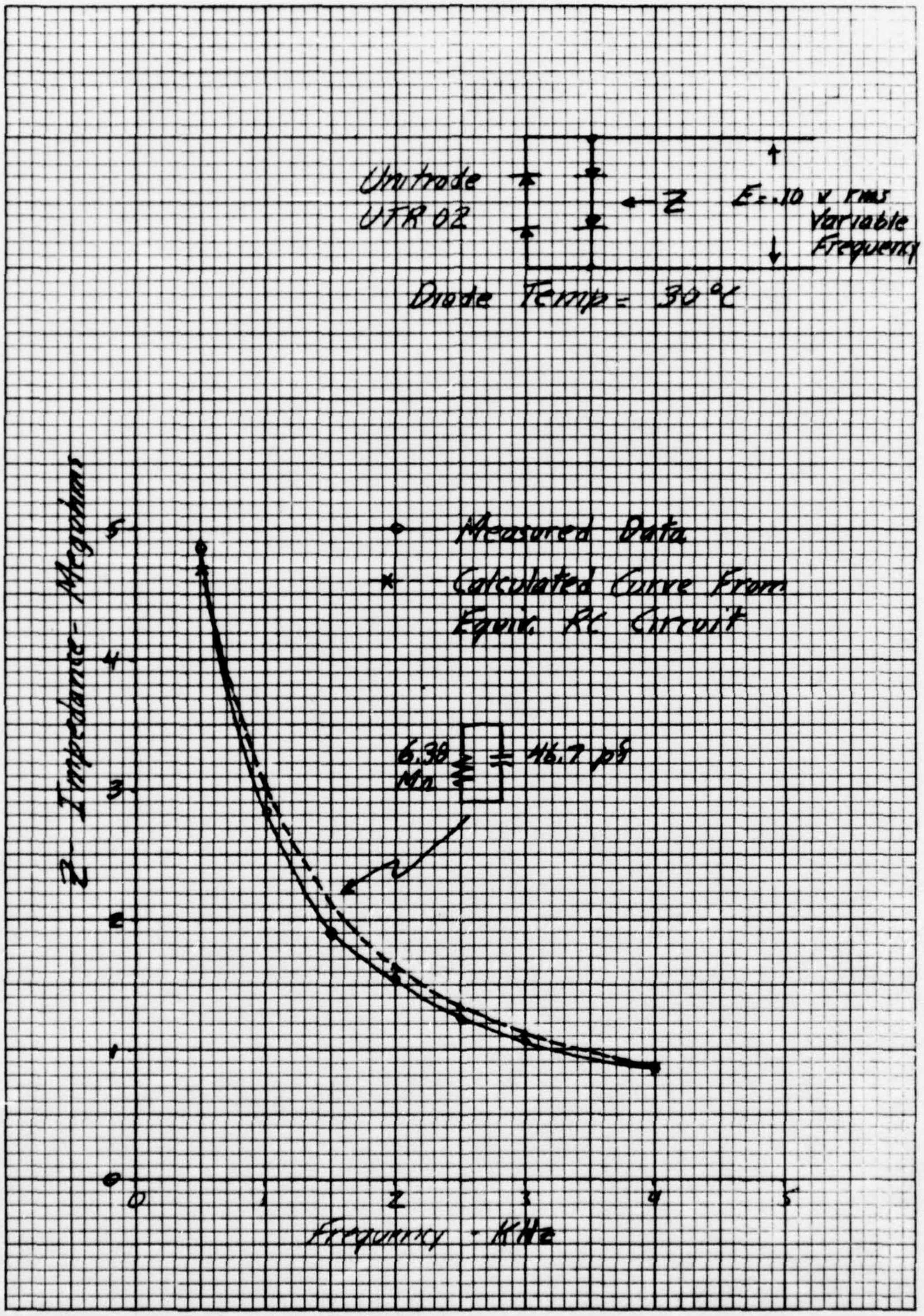



Figure 22. Diode Circuit Impedance versus Frequency

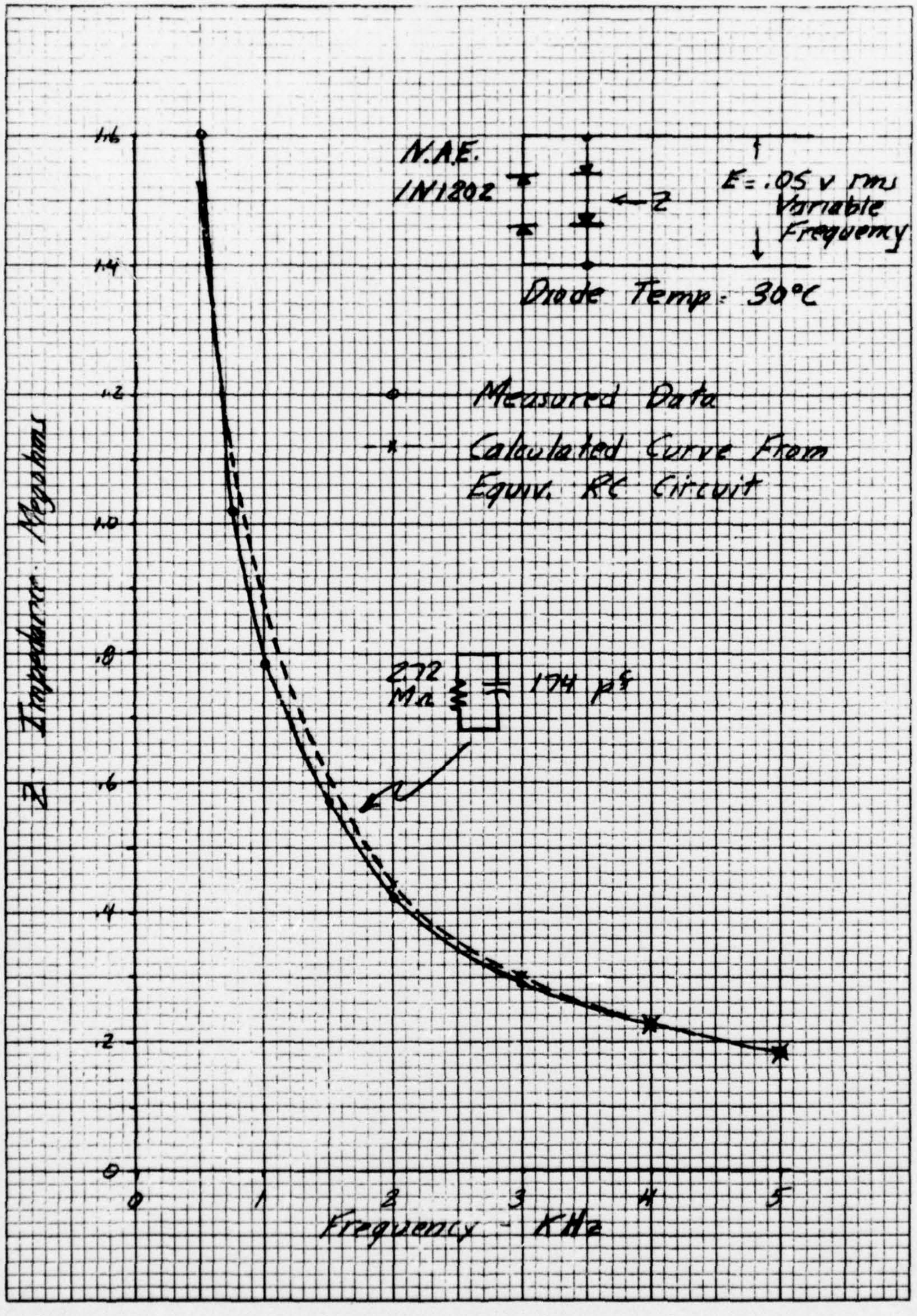



Figure 23. Diode Circuit Impedance versus Frequency

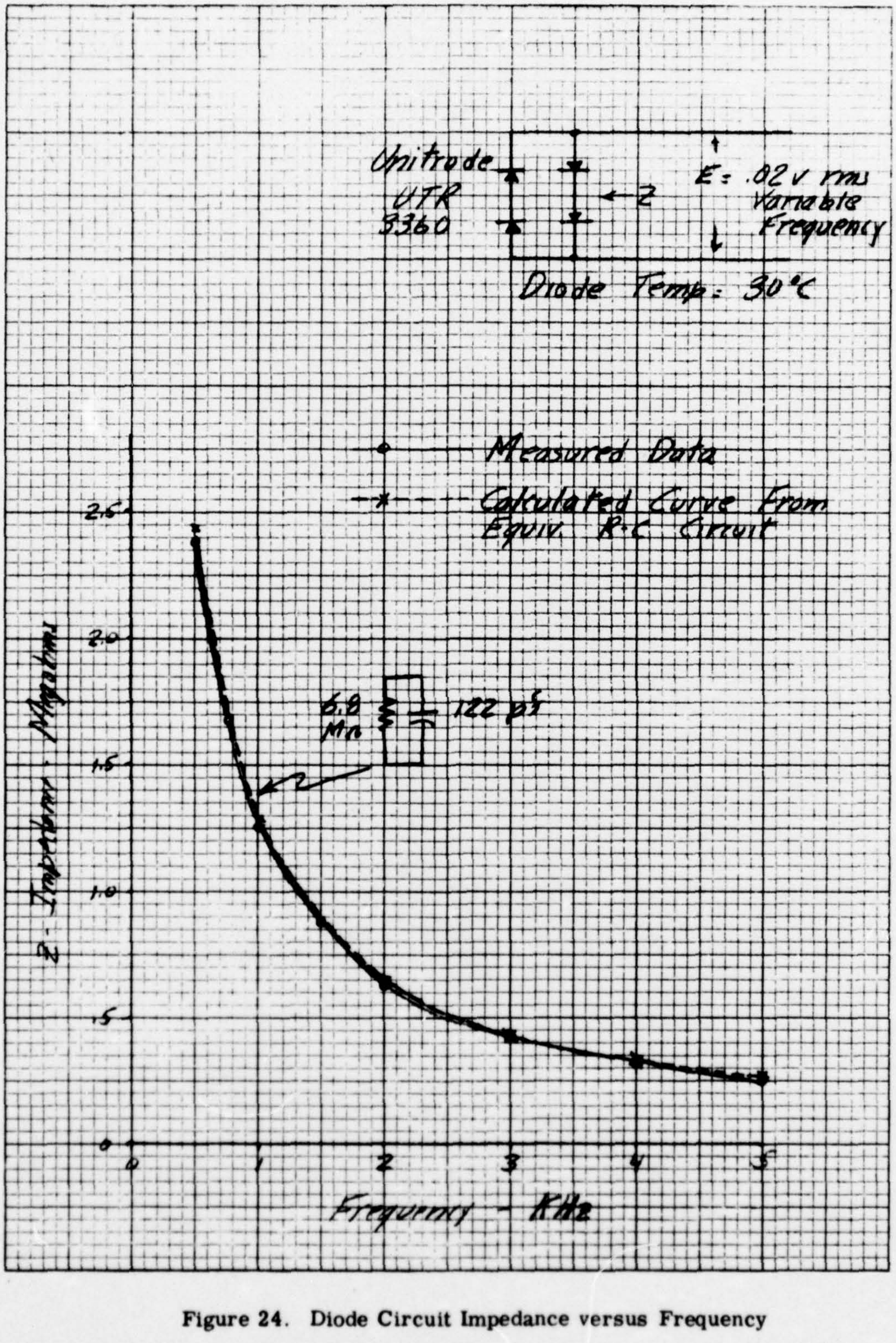
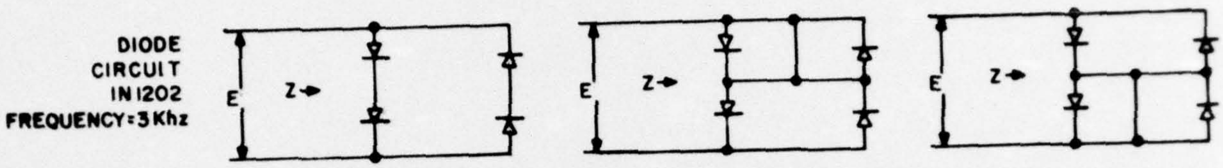



Figure 24. Diode Circuit Impedance versus Frequency




| E VOLTS | Z DIODE CIRCUIT MEG Ω |
|---|---|
| .10 | .292 |
| .20 | .280 |

| E VOLTS | Z DIODE CIRCUIT MEG Ω |
|---|---|
| .05 | .142 |
| .10 | .140 |

| E VOLTS | Z DIODE CIRCUIT MEG Ω |
|---|---|
| .05 | .130 |
| .10 | .136 |

Figure 25. Two- and Four-Diode Impedances

(b) The Magnitude of the Usable Receiver Input Signal. This signal should be less than 1.0 volt rms. At this voltage level, the series circuit of the isolating diodes and the transmitter output impedance will attenuate the receive signal. This is understandable considering Figures 17, 18, and 19. The receive signal, though, will only be attenuated during the peaks of the 1.0-volt signal at instantaneous voltages greater than 0.35 volt. (This is based on Figure 19, 76°C diode temperature, E rms = 0.25 volt. This is a region where the diode circuit is a non-linear impedance based on the fundamental voltage reading across the 1000 ohms of the test circuit being 3600 microvolts, 2nd harmonic reading being 160 microvolts, and the 3rd harmonic reading being 1000 microvolts. The minimum impedance though, will still be more than ten times the receiver input impedance of 1000 ohms.)

Therefore, since the diode impedance will be high with respect to the receiver input impedance at instantaneous voltages of less than 0.35 volt, the signal to the receiver input could have the general shape shown in Figure 26. It is conceivable that this would not be detrimental to the receiver operation.

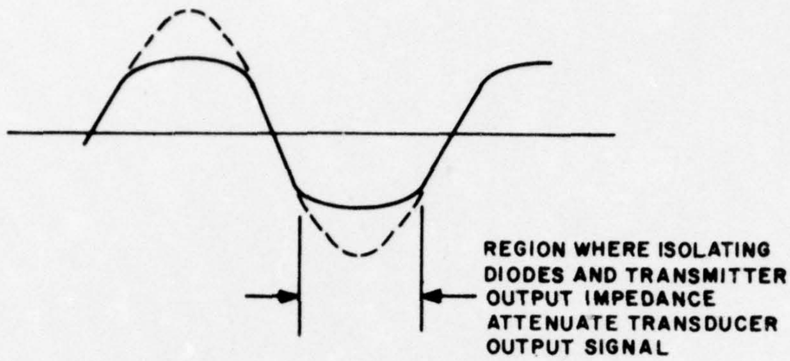



Figure 26. Probable Receiver Input Signal at 1-Volt Level

c. Underwater Explosion

The total effect of an underwater explosion upon a diode transmit switch is not known. An encouraging fact is that on the SQS-26 test, described in paragraph A.2.e. of this section, the energy content of the transient did not damage the back-to-back diode junctions at the receiver input.

2. Reed Relays

The reed relay is a device that should be considered for TR switches. The reed switch is basically two flat ferromagnetic reeds sealed in a glass tube. The two reeds overlap each other but are separated by a small air gap. When a magnetic field is applied to the reeds, the magnetic force causes the two reeds to come into contact with each other. The capacitance across the two open contacts is usually 0.2 to 1 pico-farad and the resistance across the open contacts is in terms of tens to hundreds of megohms.

The reed relay is composed of a reed switch encased in a glass bulb and a coil surrounding the glass bulb. This results in a Normally Open (Form A) relay. To obtain a Normally Closed (Form B) relay, a permanent magnet is placed near the bulb to close the reed switch. The permanent magnet and the reed switch are surrounded by the coil. Energizing the coil eliminates the effect of the permanent magnet and causes the reed switch to open. The important point in evaluating any relay is to obtain the identity of the reed switch. This is because manufacturers of the reed relay may have several sources for the reed switch for a particular reed relay catalog number.

Individual reed relays may be used as a transmit switch and also as a receive switch. Investigation of reed relays has been done by the U.S. Naval Laboratory and by the Components Section of Heavy Military Electronics Division of General Electric Company.

a. Transmit Condition

(1) Current Carrying Ability

For the constant force phased current transmitter, the requirement would be a maximum current of 2.53 amps at a frequency of 2 to 3 KHz and a duty cycle of 25 percent and a maximum pulse width of 12 seconds.

The normal operating condition for a transmit switch is for the switch to close before transmit current occurs and open after transmit current ceases. For this report, it was not considered necessary to perform any tests to determine the reed relay's ability to perform this function. This reasoning is due to the test results obtained by the U.S. Naval Applied Laboratory, Naval Base, Brooklyn, New York[1], and by the Components Section of General Electric Company's Heavy Military Electronics Department at Syracuse, N.Y.

The tests of the U.S. Naval Laboratory subjected six reeds (Hamlin DRT-5) and six reeds (Gordos MR 906) to a 100-volt, 3-KHz, 3-amp lamp load. The switches closed and opened when the 3-amp lamp load current did not exist. The 3-amp lamp load current was on for 1 second and off for 5 seconds. This test was performed for 100,000 operations without the reed relays showing any significant increase in contact resistance. The maximum contact resistance measured was less than 0.15 ohm measured under a 1.5-volt DC and 10-ma test condition.

The test performed by the Components Group of General Electric Heavy Military Electronics Department consisted of subjecting two samples of General Electric reed switch 2DR50 to a 470-volt, 60-Hz, 1.85-amp load. The switches closed and opened when the 1.85-amp load did not exist. The 1.85-amp load current was on 0.5 second and off 1.5 seconds. The two samples were each subjected to a total of 500 cycles. The contact resistance was measured at intervals during the test and the change in contact resistance was less than 12 percent[2]. The measured contact resistance was less than 0.03 ohm.

Based on the results of the U.S. Naval Laboratory and the General Electric Components group, the ability of the reed relay to perform its normal current carrying function of a transmit current of 2.53 amps is satisfactory. Consequently, no tests were performed under this study program for the current carrying ability of reed relays when the contacts are closed. The maximum unswitched current condition a reed relay could operate has not been ascertained in this program, but the literature has mentioned a figure of 5 amperes.

---

[1] U.S. Naval Applied Science Laboratory - Lab Project 9200-78

[2] Contact resistance measured with contact current at 1.0 amp DC and also at 2.0 amps DC

(2) Test Results

A condition of opening and closing the transmitter output current is usually prevented from occurring by an interlock circuit. Nevertheless, it is necessary to evaluate the performance of the transmit switch under a condition where it makes and breaks the transmit current. This transmit current could be either the normal transmit current or the transmitter short-circuit current.

This type of abnormal operation was investigated by the U.S. Naval Laboratory for a 300-volt, 3-KHz,1-amp lamp load and by the Heavy Military Electronics Division Components group for a 470-volt, 60-Hz, 1.85-amp load.

A Summary of the U.S. Naval Laboratory test results is shown below:

| Switch | |
|---|---|
| Hamlin DRT-5 | Opening the 300-volt, 3-KHz, 1-amp lamp load. Three reed switches tested; three reed switches failed. The number of operations when failure occurred: 23, 115, and 124. |
| Hamlin DRT-5 | Closing the 300-volt, 3-KHz, 1-amp lamp load. Four reed switches tested; three reed switches failed. The number of operations when failure occurred: 100, 343, 400. The unit that did not fail withstood 500 cycles. |
| Gordos MR906 | Closing the 300-volt, 3-KHz, 1-amp lamp load. Four reed switches tested; four reed switches failed. The number of operations when failure occurred: 1, 1, 1, and 13. |

Failure of the Hamlin DRT-5 and Gordos MR906 switch was indicated by the reed gap being bridged or welded together.

The test results reveal that the Hamlin DRT-5 reed switch should be considered further. Although the 1-amp lamp load will probably be less than the PASS transmitter output, it must be remembered that the ratio of hot to cold resistance of a tungsten lamp load can be around 10 to 1. Tests of the Hamlin DRT-5 switch at current levels of the PASS transmitter may reveal it to be a satisfactory transmit switch.

A summary of the tests performed by General Electric's Heavy Military Electronics Division Components Section is shown below:

| | |
|---|---|
| General Electric 2DR50 | Two reed switches tested. Each switch subjected to 250 operations of closing a 470-volt, 60-Hz, 1.85-amp load circuit; then 250 operations of opening the circuit; and then 100 operations of both opening and closing the circuit during the same cycle. No failures occured. |

The contact resistance of the GE 2DR50 switches were measured periodically during the test at contact currents of 1.0 and 2.0 amps DC. Measured contact resistance was less than 0.03 ohm, and contact resistance did not vary by more than 23 percent.

Further tests of this abnormal condition were performed under this study program. The test circuit is shown below in Figure 27.

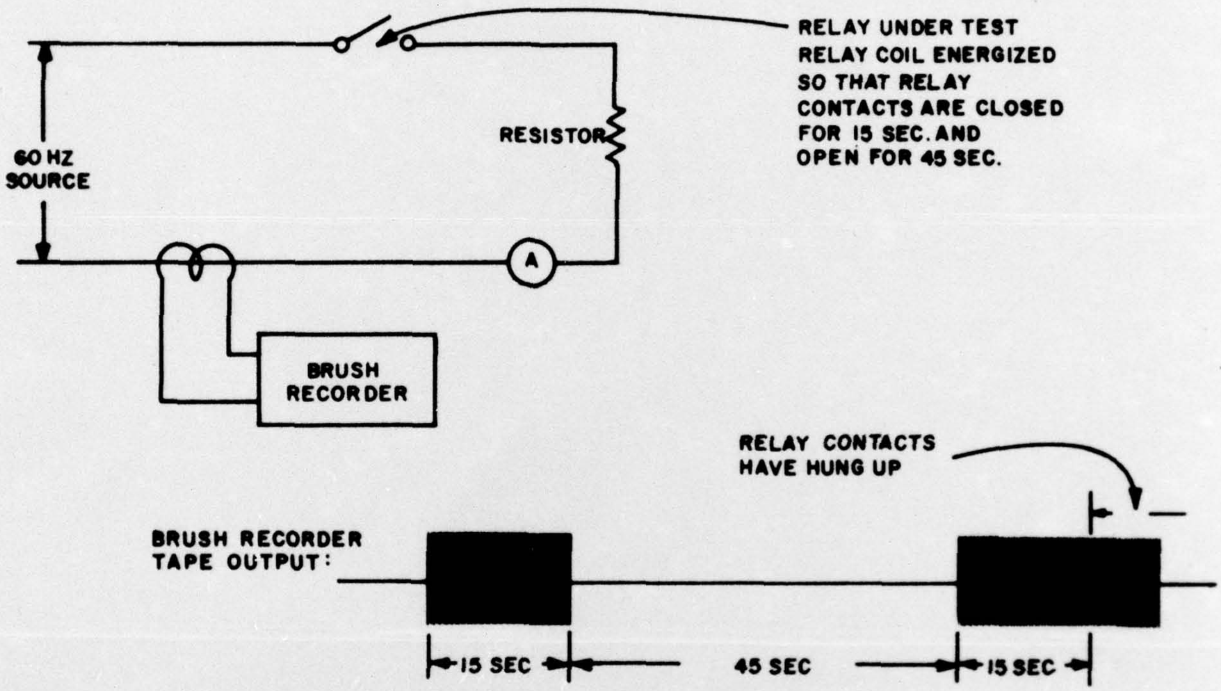



Figure 27. Relay Current Interrupting Test Circuit

The brush recorder monitored the current through the relay contacts and would give an indication when the relay contacts hung up, due either to welding of the contacts or bridging of the gap between the contacts.

The results obtained for the reed switches tested are shown in Table 2.

TABLE 2. RELAY CURRENT INTERRUPTING – TEST RESULTS

| Relay Switch | Contact Rating | | Test Circuit | | Results |
|---|---|---|---|---|---|
| | Resistive Load | Dielectric Strength | Volts | Ampere Resistive Load | |
| Gordos MR 990 Sample No. 1 | 100 VA DC | | 470 | 4.7 | Contacts remained closed at end of 2nd cycle |
| Gordos MR 990 Sample No. 2 | 100 VA DC | | 470 | 4.7 | Contacts remained closed at end of 1st cycle |
| Gordos MR 990 Sample No. 3 | 100 VA DC | | 470 | 2.5 | Contacts remained closed at end of 10 cycle |
| Gordos MR 990 Sample No. 4 | 100 VA DC | | 470 | 2.5 | Contacts remained closed at end of 2nd cycle |
| Gordos MR 906 Sample No. 1 | 15 VA DC | 500 v rms 60 ~ | 470 | 4.7 | Contacts remained closed at end of 38th cycle |
| Gordos MR 906 Sample No. 2 | 15 VA DC | 500 v rms 60 ~ | 470 | 4.7 | Contacts remained closed at end of 1st cycle |
| Gordos MR 936 Sample No. 1 | 15 VA DC | | 470 | 4.7 | Contacts remained closed at end of 4th cycle |
| Gordos MR 936 Sample No. 2 | 15 VA DC | | 470 | 4.7 | Contacts remained closed at end of 4th cycle |
| DRS-1 Sample No. 1 | 25 VA DC | 500 VDC | 115 | 4.5 | Contacts went thru 240 cycles satisfactorily. Test discontinued. |
| C. P. Clare Sample No. 1 | 15 VA | 500 v* rms 60 ~ | 470 | 9.6 | Contacts remained closed at end of 1st cycle |
| RP-9271-G12 Sample No. 2 | resistive | | 470 | 9.6 | Contacts remained closed at end of 1st cycle |
| modified by Automatic Electric Sample No. 3 | | | 470 | 7.0 | Contacts remained closed at end of 1st cycle |
| Company Spec Sample No. 4 | | | 470 | 6.0 | Contacts remained closed at end of 1st cycle |
| Sample No. 5 | | | 470 | 4.7 | Contacts remained closed at end of 357th cycle |
| Sample No. 6 | | | 470 | 4.7 | Contacts went thru 151 cycles satisfactorily. Test discontinued. |
| Sample No. 7 | | 500 v* rms 60 ~ | 115 | 4.7 | Contacts went thru 25 cycles satisfactorily. Test discontinued. |

C. P. Clare RP-9271-G12 Sample No. 6 - Visual examination of reed switch: inside of glass bulb near contacts has been blackened by the arcing contacts. Contacts have blackened area.

C. P. Clare RP-9271-G12 Sample No. 7 - Visual examination of contacts show slight evidence of arcing.

*Two sample switches withstood 650 VAC rms 60 ~

b. Receive Condition

(1) Current Carrying Capability

A reed relay may be used as a receive switch. During the receive inter val, the receive switch will be closed. It is necessary that the resistance of the receive switch contacts be low compared to the receiver input impedance. The receiver input current will fall into the range of $1 \times 10^{-9}$ amps (1 microvolt into 1000 ohms). The 1-microvolt minimum signal is, of course, not realistic considering the noise ambient.

The minimum of the probable range of current ($1 \times 10^{-9}$ amps to $1 \times 10^{-3}$ amps) is out of the range of what some relay manufacturers recommend as a current level to measure contact resistance. One manufacturer recommends a minimum current range of $1 \times 10^{-6}$ amps. One General Electric purchase print for a reed relay for a low-level switching application specifies contact resistance at a 10-microamp level.

(2) Contact Resistance

Under this study program an attempt was made to obtain an indication of the contact resistance of reed relays at current levels of $1 \times 10^{-9}$ amps. The circuit was as shown in Figure 28.

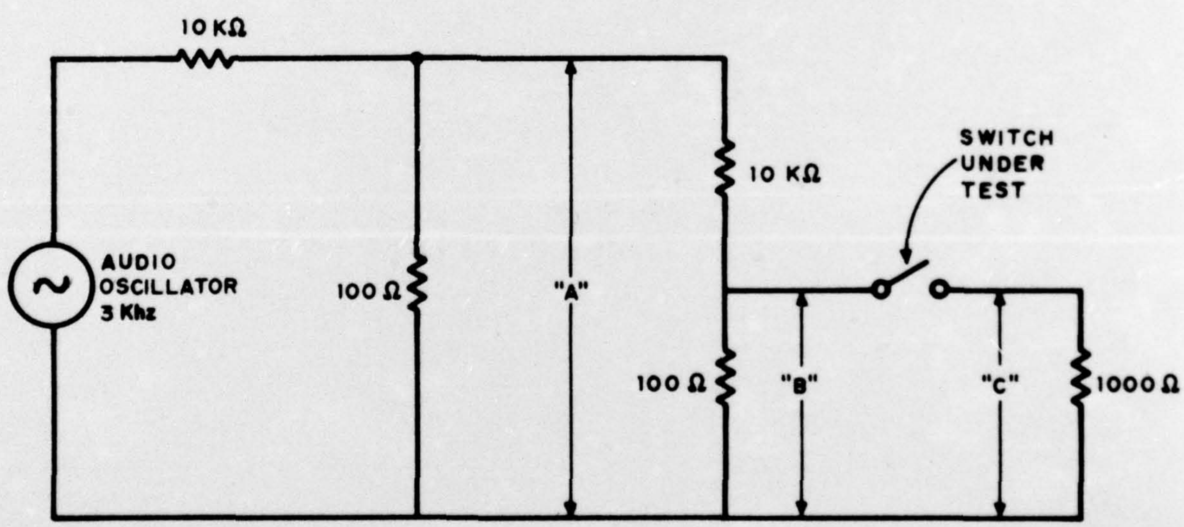



Figure 28. Circuit to Measure Contact Resistance

The voltages at A, B, and C were measured by a Stoddard Radio Interference Field Intensity Meter NM-40A. The Stoddard meter can be used as a selective frequency tuned voltmeter and is able to measure voltages of less than one microvolt. The test procedure was to measure the voltages at A, B, and C with the switch under test open. The object of measuring the voltage at A was to have an added assurance that the readings were correct since the voltage at B should be 1/100 of the voltage at A. The voltage at C was read to determine the degree of pickup existing.

The following reed relays were tested initially in the circuit before the contacts were subjected to any current.

Gordos MR 936 Sample No. 1

C. P. Clare RP-9271-G12 Mod. AEC Sample No. 1

C. P. Clare RP-9271-G12 Mod. AEC Sample No. 5

C. P. Clare RP-9271-G12 Mod. AEC Sample No. 6

C. P. Clare RP-9271-G12 Mod. AEC Sample No. 7

The voltages at B and C were compared with the reed relay closed and open. With the reed relay closed, no appreciable difference was observed between the voltage readings at B and C when the voltage at B and C was about 1 microvolt. The conclusion being that with a current of $1 \times 10^{-9}$ amps, the contact resistance is insignificant compared to 1000 ohms. It is estimated that it would have been possible to detect a contact resistance that was in the order of 1/10 to 1/5 of 1000 ohms. With the reed relay open, the voltage at C was between 0.1 and 0.2 microvolts while the voltage at B remained at about the 1 microvolt. This gives an indication of the pickup of the circuit.

(3) Test Results

The U. S. Naval Laboratory has conducted tests of reed switches performing their normal receive switch function. In their test, relays were subjected to a 100-microvolt 3-KHz signal into a 1000-ohm load. The relays were closed for 5 seconds and then opened for 1 second. Their conclusions were that the reed relay performed its receive switch function successfully for the 100,000 operations (length of test).

The relays tested were

| Quantity | Reed Switch |
|---|---|
| 6 | Hamlin DRS-1 |
| 6 | Gordos MR 906 |

The receiver input is normally protected by back-to-back diodes. If the receive switch closes during the transmit cycle, it will be subjected to the short-circuit current output of the transmitter. Thus, the receive switch has a similar abnormal condition as the transmit switch. Table 2 of this report describes the test results of reed relays opening and closing a 470-volt, 60-Hz circuit of various ampere loads. The tests of some of these relays were interrupted and the reed switch contact resistance was measured in the circuit. (See paragraph (2) and Figure 28 above.) In this manner, it was hoped to determine if the reed relay could still perform its normal function after it had been subjected to the abnormal condition.

The following are the test results:

C.P. Clare RP-9271-G12 Model A.E. Co. Sample No. 5

1. Contacts initially tested in circuit (Figure 28) with B voltage = 1 microvolt.

   Contact resistance small compared to 1000 ohms.

2. Contacts open and close 470-volt, 4.7-amp resistive load for 243 cycles without contacts hanging up (Table 2).

3. Performed Step 1. Contact resistance small compared to 1000 ohms.

C.P. Clare RP-9271-G12 Model A.E. Co. Sample No. 6

1. Contacts initially tested in circuit (Figure 28) with B voltage = 1 microvolt.

   Contact resistance small compared to 1000 ohms.

2. Contacts open and close 470-volt, 4.7-amp resistive load for 79 cycles without contacts hanging up (Table 2).

3. Repeated Step 1. Contact resistance small compared to 1000 ohms.

4. Repeated Step 2 for 72 more cycles without contact hanging up.

5. Repeated Step 1. Contact resistance small compared to 1000 ohms.

6. Test discontinued.

C.P. Clare RP-9271-G12 Model A.E. Co. Sample No. 7

1. Contacts initially tested in circuit (Figure 28) with B voltage = 1 microvolt.

   Contact resistance small compared to 1000 ohms.

2. Contacts open and close 115-volt, 4.7-amp, 60-Hz resistive load for 5 cycles without contacts hanging up (Table 2).

3. Repeated Step 1. Contact resistance small compared to 1000 ohms.

4. Repeated Step 2 for 20 more cycles.

5. Repeated Step 1. Contact resistance small compared to 1000 ohms.

6. Test discontinued.

The conclusion of these tests is that the occurrence of an abnormal condition whereby the receive switch closes and opens during a transmit cycle will not necessarily cause the receive switch to have excessively high contact resistance and cause it to perform its normal receive switch function unsatisfactorily.

c. Cost and Wattage Ratings

It is possible to obtain reed relays consisting of one coil and several reed switches. The cost per switch of such a relay is, of course, less than a relay with only one switch. It is estimated that the cost per switch for a reed relay approach will be between $3.50 and $1.50.

The wattage requirements per switch is also dependent on the number of switches per relay. The estimated coil wattage requirement per switch will be between 100 and 300 milliwatts.

3. Armature Relay

The Couch Ordnance Company manufactures an armature relay designed for a sonar TR switch application. The relay is Couch's Type X656 and is presently being used in a sonar system. The relay is a double-pole, double-throw unit, oil filled, and the contacts have higher than normal contact pressure. Its transmit contacts would be able to handle the transmit current under normal conditions. The vendor's outgoing test requires the receive contacts to have a contact resistance of less than 50 ohms at a current level of $10 \times 10^{-7}$ amperes with 1000-Hz power.

One sample was available for our testing. Our test consisted of simulating an abnormal condition for the receive switch. The receive switch opened and closed a 470-volt, 60-Hz, 4.7-amp resistive load circuit. The cycling was such that the receive contacts were closed for 15 seconds and open for 45 seconds. A pair of receive contacts was subjected to a total of 400 cycles. At the end of the 100th, 200th, and 400th cycle, the receive contacts were tested for contact resistance in the circuit described in paragraph D. 2. b. (2) above. This contact resistance test revealed that the contact resistance was small compared to 1000 ohms.

The disadvantage of the armature relay is in its life. Usually, life for a hermetically sealed electromechanical relay is 100,000 operations at rated load. It is possible to specify a life in the millions of operations with an allowance (less than 5 percent) for electrical failures of the contacts. Whether this is acceptable or not would depend on the system requirements.

4. Vacuum Relay

The Jennings Radio Manufacturing Corporation has recently issued a preliminary specification for a small (1.75 x 1.25 x 50-inch cube) single-pole, double-throw vacuum relay. The contact capacitance is less than 2 picofarads. The expected life is 2 million operations. The advantages of the relay would be its attenuation characteristics, and the interrupting current rating of the contacts. Vacuum switches find their application in circuits requiring high hold-off voltages between open contacts. This relay is tentatively rated at a test voltage of 2 kv, 60 Hz between terminals. The disadvantages of this type of relay will be its cost (approximately $20 each) and the required coil power of approximately 3/4 watt.

5. Mechanical Switch

The present SQS-26 sonar system uses a mechanical TR switch. Consideration has and is being given to replace the mechanical switch approach. It was felt that no contribution could be made by studying a mechanical TR switch approach for the PASS.

## E. PACKAGING OF TR SWITCH

The packaging arrangements of a TR switch, consisting of a diode transmit switch and a reed relay receive switch or a reed relay transmit and receive switch, are numerous. This is because it is possible to obtain reed relays with one coil actuating several reed switches. At least five Form A switches may be obtained in one relay. A relay with four Form A and four Form B switches can also be obtained in one relay.

The U.S. Naval Applied Science Laboratory performed a test on a relay consisting of a single coil actuating four reed switches. The object of the test was to determine the degree of isolation that existed between reed switches. A 300-volt, 3-KHz, 1-amp signal was applied to a reed switch with the three remaining reed switches disconnected from any external circuit. The amount of isolation between the reed switch with the 1-amp signal and the remaining reed switches was greater than 100 db.

## F. LOCATION OF THE TR SWITCH

The basic transmitter, transducer, and receiver interconnection is again shown in Figure 29 below:

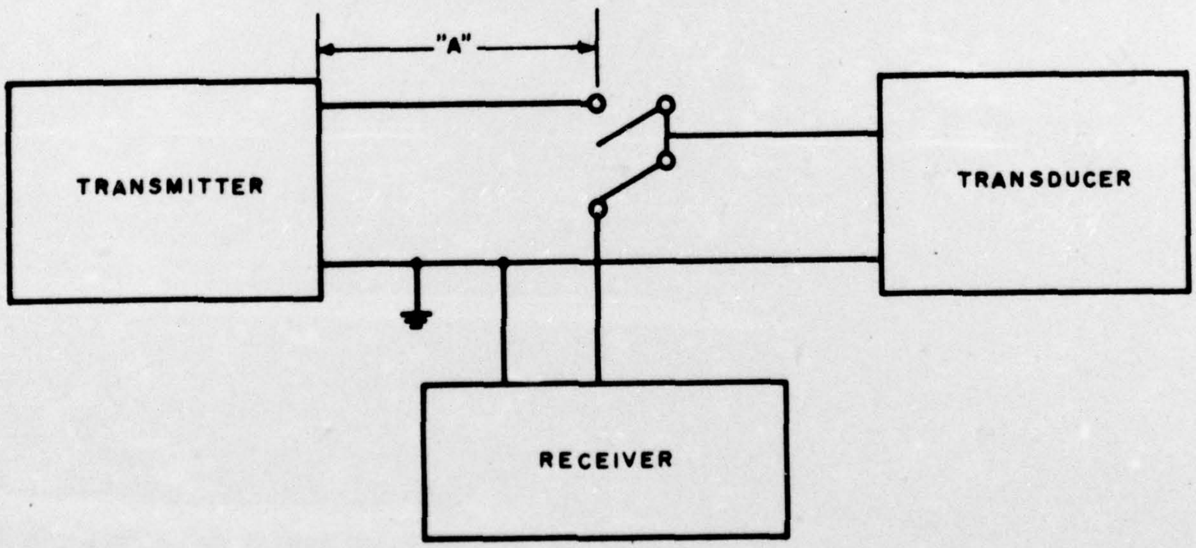



Figure 29. Transmitter, Transducer, and Receiver Interconnections

It is recommended that the TR switches be located in a separate cabinet. A transmit switch, such as the diode circuit, might suggest that it be located in the transmitter module. But this location would not be desirable because it adds "A" length of cable to the high side of the receiver input and this would be an added noise source.

The Partial Array Confidence Tests offer an opportunity to obtain operating experience with proposed TR switches. The proposed barge test involves 225 modules. It is conceivable that several TR circuits (in test groups of 50) could be evaluated.

## SECTION III

## CONCLUSIONS AND RECOMMENDATIONS

The recommendations drawn from the work covered by this report cover two areas. They are:

(1) Type of TR switch to be seriously considered.
(2) Location of the TR switch.

### A. TYPES OF TR SWITCHES TO BE CONSIDERED

#### 1. Transmit Switch

The results of this study show that the diode circuit and the reed relay should be considered as the transmit swtich. The present higher cost of the diode circuit as compared to the reed relay should not be a deterrent at this time. The future downward trend of semiconductor prices, reliability, and simplicity of the circuit make this type of transmit switch desirable.

The promising diodes are the 1N1128A and the Unitrode UTR62. The diode characteristics that make it a desirable transmit switch are areas that are not covered by the specifications. These areas are junction capacity, junction capacity as a function of temperature, the diode's forward and reverse resistances at small voltage levels as a function of temperature, and the degradation of these characteristics as a function of time. These are the areas that need to be covered in a specification.

A sonar system would require that a diode transmit switch package be a modular assembly that can easily be inserted in the TR cabinet. This assembly could contain several diode transmit switches and could even contain the circuit's receive switch also. Packaging must contribute minimum capacity between anode and cathode leads.

The degradation of the attenuation characteristics(Figure 19) of the diode circuit, as the diode temperature increases, is an important characteristic to consider. Consideration of the maximum ambient, maximum transmitter output current under normal conditions for the finalized transmitter, and diode packaging arrangement will give an indication of the diode junction temperature. If this temperature is such that the diode circuit's impedance does not provide adequate attenuation, it will require that the TR cabinet be cooled to obtain the needed attenuation.

The reason for giving further study to a reed switch for the transmit switch function is its cost advantage over the diode circuit. Another reason is that the transmitter output voltages and currents for the normal and abnormal conditions are not finalized. For a group of reed relays that satisfactorily perform the normal operating conditions, the abnormal conditions should be the governing factor for selecting the transmit relay. This is because a failure of the interlock circuit and/or vibration at the reed switch's resonant frequency may cause the reed switch to open and close the transmit circuit.

The reed relay switches that should be considered are the C. P. Clare RP-9271-G12 (rated 15 watts) as modified by an Automatic Electric Company specification, General Electric 2DR15 and the 2DR50. The General Electric 2DR15 switch and the CP Clare RP-9271-G12 switch are both used in the particular Automatic Electric Company relay tested. The 2DR50 (rated 50 watts) was tested by the Components Section of Heavy Military Electronics Division, and based on their results, it should receive further consideration. The Hamlin DRT-5 switch should also be considered based on the U.S. Navy Applied Science Laboratory tests.

2. Receive Switch

It is recommended that the reed relay be seriously considered for the receive switch because of its cost advantage and its ability to perform millions of operations of low-level switching. Again, for a group of reed relays that satisfactorily perform the normal operating conditions, the abnormal operating conditions should be the governing factor for selecting the receive relay. Based on the reasons described for the transmit switch, the C. P. Clare RP-9271-G12, General Electric 2DR15 and 2DR50, and the Hamlin DRT-5 reed switches should be further considered.

B. LOCATION OF THE TR SWITCH

It is recommended that the TR switch system be located externally to the transmitter module; probably in a separate cabinet as close to the array as feasible. The Partial Array Confidence Tests should incorporate this concept with sufficient number of this proposed TR switches to permit evaluation under operating conditions.