

**DECLASSIFIED**

NRL REPORT R-3331

COPY NO. 7

*FL-3331*

# KINGFISHER "E" COMMAND CONTROL SYSTEM



**DECLASSIFIED by NRL Contract  
Declassification Team**

Date: 29 DEC 2016

Reviewer's name(s): [Redacted]

Declassification authority: NAVY DECLASS  
GUIDE/NAVY DECLASS MANUAL, 11 DEC 2012,  
D2SERIES

DECLASSIFIED: By authority of

DOD DIR 5200.10

Date

*[Signature]*

Classified by [Redacted] [Redacted] Code



**NAVAL RESEARCH LABORATORY**

**WASHINGTON, D.C.**

DISTRIBUTION STATEMENT A APPLIES

Further distribution authorized by [Redacted]  
UNLIMITED only.

**SECRET**

**DECLASSIFIED**

chod.  
des.  
capilla  
point  
walls.

present  
to  
It is  
nt

e,  
and  
May

—

—

~~SECRET~~  
DECLASSIFIED

DECLASSIFIED NRL REPORT R-3331  
COPY NO. C30

UNCLASSIFIED

# KINGFISHER "E" COMMAND CONTROL SYSTEM

James T. Burke

August 9, 1948

UNCLASSIFIED

UNCLASSIFIED

Approved by:

Mr. H. L. Flowers, Head, Command and Report Links Section  
Dr. R. M. Page, Superintendent, Radio Division III



**NAVAL RESEARCH LABORATORY**

CAPTAIN H. A. SCHADE, USN, DIRECTOR  
**WASHINGTON, D.C.**

**JPL LIBRARY**  
CALIFORNIA INSTITUTE OF TECHNOLOGY

~~SECRET~~  
DECLASSIFIED

DECLASSIFIED

DECLASSIFIED



DISTRIBUTION

AN-GM Mailing List  
Parts A and C (Copy Attached)

DECLASSIFIED



## CONTENTS

Abstract	iv
Problem Status	iv
Authorization	iv
INTRODUCTION	1
PURPOSE OF COMMAND CONTROL SYSTEM	1
CHOICE OF SYSTEM	2
DESCRIPTION OF SYSTEM	2
CIRCUIT DETAILS	2
ARRANGEMENT OF CIRCUIT COMPONENTS	6
TESTS	16
CIRCUITS CONSIDERED BUT NOT USED	18
IMPROVEMENTS MADE	20
CONCLUSIONS	21
RECOMMENDATIONS	21
ACKNOWLEDGMENTS	21

DECLASSIFIED

SECRET

#### ABSTRACT

A version of the Hornet command control system for the mid-course guidance of Kingfisher "E" and various modifications of the system which have been considered, are discussed in this report. This system is an "on-off" type utilizing a fire control radar (Radar Mk 25) as the transmitting link. Control information is sent to the missile by selection of one of six pulse repetition rates for the radar. The missile-borne equipment has been designated as "Radar Set AN/DPW-2(XN-1)." The individual circuits used in the system are presented in schematic form with a description of their operation.

#### PROBLEM STATUS

This is an interim report describing progress made in adapting a Project Hornet Command Guidance System to fit the requirements of the Kingfisher "E" missile.

#### AUTHORIZATION

NRL Problem No. R05-04R

DECLASSIFIED

SECRET

## KINGFISHER "E" COMMAND CONTROL SYSTEM

### INTRODUCTION

The system referred to as Project Hornet is composed of a number of guidance systems capable of being used with a fire control radar for guiding a missile to a target along a designated course.

An "on-off" five-channel system of Project Hornet is being adapted as the guidance system for the Kingfisher "E" missile.<sup>1</sup> This missile, under cognizance of the Bureau of Ordnance, is being developed to carry a torpedo from a destroyer deck and drop it within five hundred yards of a submerged target or a surface target located at ranges up to 20 miles from the destroyer. The following is a discussion of the adaptation of the Project Hornet command control system as the guidance system for the Kingfisher "E" missile. The integration of this command link into the missile system is not the responsibility of this Laboratory and is discussed elsewhere.<sup>2</sup>

### PURPOSE OF COMMAND CONTROL SYSTEM

The command guidance system to be used in Kingfisher "E" (XSUM-2) must make use of a shipboard command computer, Radar Equipment, Mark 25, and an autopilot. The computer is supplied with missile present position data from the Mark 25 radar, and with target present position data from some other source. Given the above data, the computer supplies through the command link the necessary correction to bring the missile on the proper course. Data from the computer will be used to establish a reference with which the range and azimuth (supplied by the Mark 25 radar) of the missile can be compared. The command system is required to override a preset guidance system in the missile; commands will be transmitted by the tracking radar and will be controlled by the computer. Under this arrangement the command system will be required to direct the missile to exercise simple turns, to advance or retard the airlog setting of the missile preset system, and to dive the missile at the proper point near the end of the course.<sup>3</sup>

<sup>1</sup> BuOrd letter S78-11(126) to NRL dated July 1947.

<sup>2</sup> Quarterly Progress Reports on Project Kingfisher, National Bureau of Standards, Dec. 31, 1947, No. 5, - on March 31, 1948 - No. 6.

<sup>3</sup> R. G. Wilson et al., Preliminary Report "Guidance and Control of Kingfisher E," Goodyear Aircraft Co., Ger 683, August 25, 1947.

DECLASSIFIED

2

NAVAL RESEARCH LABORATORY

SECRET

## CHOICE OF SYSTEM

The command control system is not required to supply intelligence in the order of accuracies that would be required for a pin-point target (direct hit on target). The Project Hornet command control system was selected because of the simplicity of the system, the small number of components required, the simplicity of operation, and the fact that one such system has been built and tested by the Naval Research Laboratory. It was believed that the "on-off" system was satisfactory and that it would be possible to use the system to a limited extent for proportional control. The proportional control is to be accomplished by time-sharing of the left and right channels.

The Project Hornet system may be used with the radar while the radar tracks the missile and sends out control information. The two functions must be performed simultaneously without jeopardizing the effectiveness of either.

## DESCRIPTION OF SYSTEM

The Kingfisher "E" command control system for mid-course guidance operates using five different discrete pulse repetition rates (PRR) on the radar for the five channels of control desired. For example, the presence of the PRR for channel number one would mean that the control function assigned to that channel would be performed when the radar was being triggered at the first PRR. This requires that the radar be able to track the missile automatically at all times and be capable of being triggered at a wide range of pulse repetition rates from 1500 to 2500 cps. The radar must provide range and azimuth information to the antenna-mount positioning equipment as well as to the command computer and coder. A block diagram of the system is shown in Figure 1. The computer energizes the proper channel in the command coder, one of six Wien-bridge oscillators tuned to the appropriate channel frequency. The computer as shown in Figure 1 receives range and azimuth information from the missile-tracking radar, and target information from the target-tracking equipment. The computer assimilates the information and automatically initiates the operation of the proper control channel. The channel frequency selected is used as the radar repetition rate, permitting the radar to perform its normal function, as well as to send "on-off" intelligence to the missile.

At the missile, the pulses are received by a superheterodyne receiver, the output of which triggers a pulse stretcher to increase the energy level. The output of the pulse stretcher is coupled to six selective parallel-T amplifier filters by a cathode follower. The filters are each tuned to one of the channel frequencies, and their outputs are used to energize relay amplifiers which operate the auto-pilot in the missile. This command control system is one link of a complete servo-loop composed of the radar and its servo-tracking mechanism, the command control system, the missile airframe, and the missile servo-guiding system. There is also the interconnecting and feedback link, in the radar frequency path, between the radar and the missile.

## CIRCUIT DETAILS

The circuits of the command system will be described in the following order: command coder (shipborne unit), command receiver (airborne unit), command decoder (airborne unit).<sup>4</sup>

---

<sup>4</sup> No description or discussion will be made of the beacon except to point out its use and to show its position in the block diagram, since it will be described fully in a companion report now being prepared.

DECLASSIFIED

SECRET

SECRET

SECRET

DECLASSIFIED

DECLASSIFIED

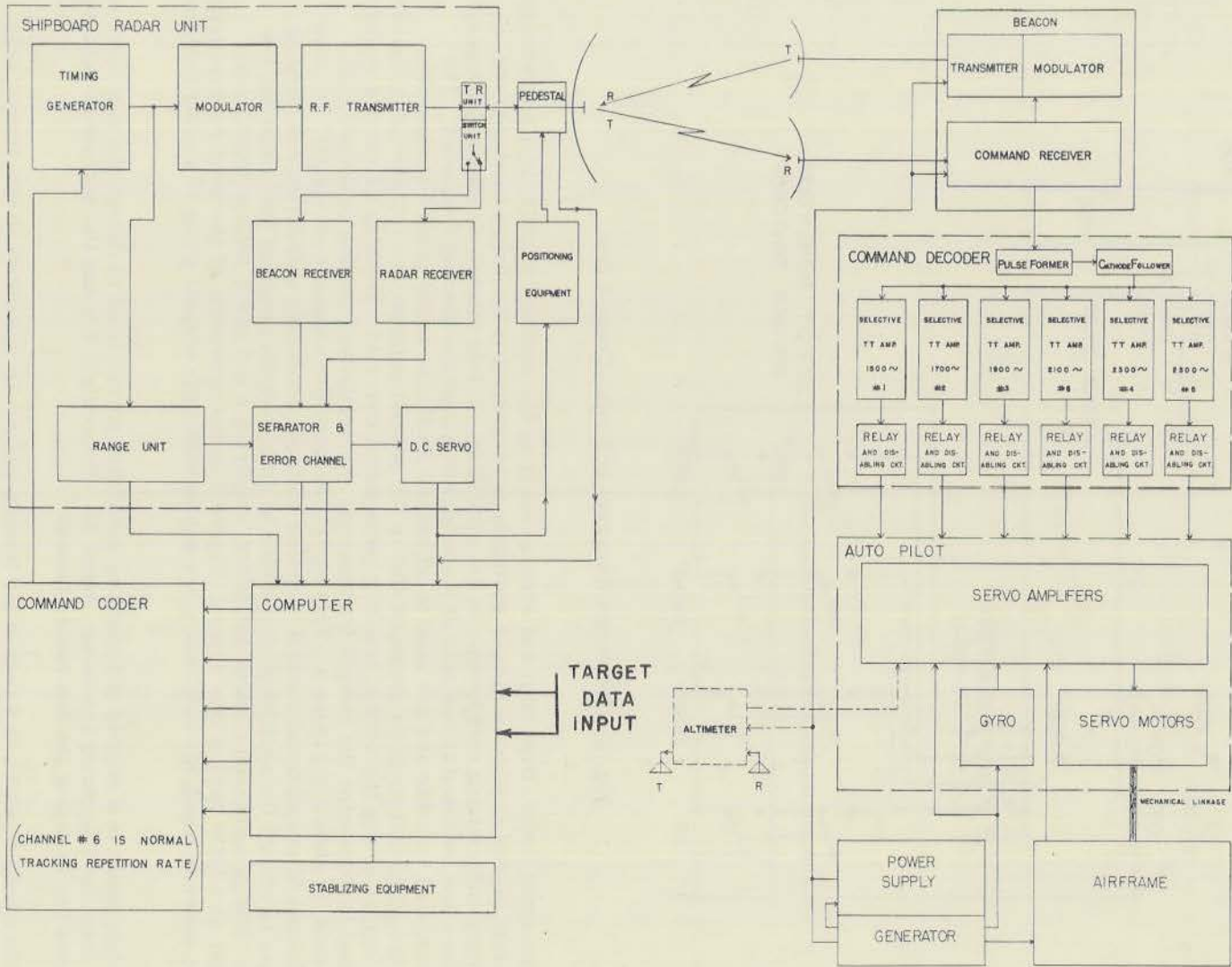


Fig. 1 - Block Diagram Kingfisher "E" Command Control System

UNCLASSIFIED

SECRET

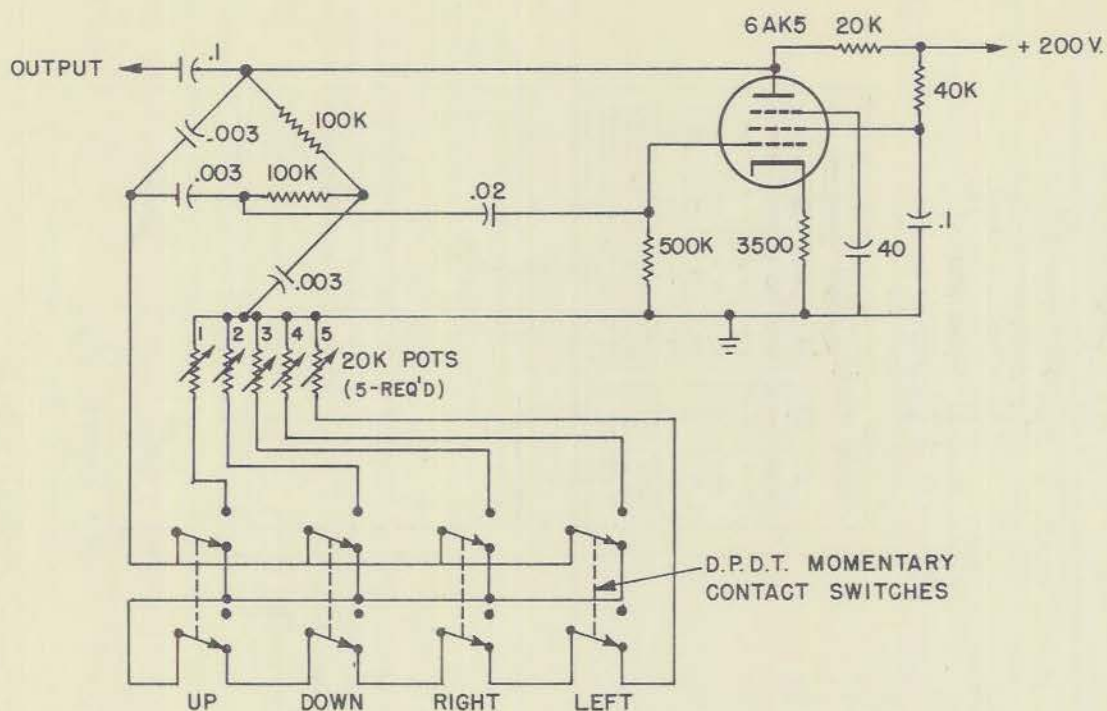


Fig. 2 - Schematic Diagram of Flight-Control Box

The command coder, first built and used as early as the summer of 1946, is a Wien-bridge oscillator circuit in which a simple switching arrangement is employed to change the frequency-determining components in the oscillator. In this circuit, as shown in Figure 2, resistors are switched in one arm of the bridge to select the channel frequency. The resistors are variable and are used to adjust the oscillator to the proper channel frequencies. The circuit is so arranged that in the normal position one resistor is in the arm of the bridge giving the normal tracking pulse repetition rate. The four remaining resistors<sup>5</sup> are used to determine the control frequencies. An oscillator, similar to the one just described, is shown in Figure 3. This figure includes five channels of "on-off" and also one channel of proportional control, together with the necessary amplifying and clipping circuits to change the oscillator sine waves to pulse outputs required for triggering the radar. The proportional control oscillator, requiring a d-c error voltage input, is described at a later part of this report. Figure 4 is the schematic of the most recent design of this coder in which six oscillators are shown with their outputs going to a control junction box.

Also shown is a clipper and blocking oscillator circuit used to change the sine wave into pulse form for triggering the Radar, Mark 25. The control box has the necessary switching functions for selecting the desirable channel.

The receiver which is a part of the beacon will not be discussed in this report; only pictures and schematics will be shown. The block diagram of the airborne equipment

<sup>5</sup> There were only four channels in this first unit.

SECRET



## DECLASSIFIED

6

NAVAL RESEARCH LABORATORY

SECRET

including the decoder and beacon is shown in Figure 5. Photographs (Figure 6) show the complete system in wooden mockup form and also the equipment (Figure 7) as constructed by the Naval Research Laboratory. Upon inspection of Figure 5, it will be noted that the one receiver is used to trigger the beacon as well as the decoder. The radar pulse is detected by the receiver and used to trigger the decoder.

The decoder begins its operation on the received signal by first increasing the pulse energy. The pulse-former accomplishes this by increasing the pulse width. This is one form of a multi-vibrator; its schematic is shown in Figure 8. The pulse-former is coupled to the selective parallel-T amplifier circuits by a conventional cathode follower. The selective circuits (Figure 8) include one parallel-T whose null frequency is that of the frequency to be selected and passed. The parallel-T is coupled in the feedback path of a conventional audio amplifier. Impedance-matching the network in the feedback path is accomplished by cathode followers as shown. At the null frequency of the parallel-T network there exists a maximum attenuation; thus a very small percentage of degenerative feedback exists, and the output from the amplifier is a maximum. At other frequencies the attenuation factor of the parallel-T is decreased.

The frequency characteristics of the five selective channels (second experimental decoder) are shown in Figure 9. These curves are plotted showing voltage output versus frequency. The input voltage was constant for all measurements. Following each of the selective amplifiers is a circuit designed to eliminate the cross-talk between channels. This is accomplished by amplifying the incoming signal and rectifying a portion of the same. The resulting negative d-c voltage is applied to the grids of each adjoining channel, and biases them far below cut-off. This circuit can permit five or ten percent cross-talk in the selective circuit and yet prevent interference between channels. The relays used in this circuit are energized (closed), at a current of approximately 6 ma and opened at approximately 4 ma.

In the third experimental decoder unit (Figure 10) a thyratron is used as the relay tube (2D21) in place of the 6J6. The cross-talk circuit is replaced by using extra contacts on the relays for de-energizing adjoining channels. This allows for considerable reduction in the number of tubes and components. The frequency response curves for the five channels in the Model XA-III decoder are shown in Figure 11. The differences in the peak outputs of each channel are caused by the variation in the peak attenuation of the filters and in the tube characteristics.

### ARRANGEMENT OF CIRCUIT COMPONENTS

The components involved in the circuits of the coder and decoder, except for the parallel-T, are in general not subject to any critical physical arrangements. The parallel-T components must be so arranged physically as to give the minimum of capacity coupling between input and output. This is necessary because the transfer impedance at the null frequency should be very high for minimum transfer of signal at that frequency. At present the parallel-T networks are required to have a peak attenuation at the null frequency of not less than 50 db. The physical arrangement of this circuit is shown in Figure 12. Figure 13 shows the method for assembly and plotting of the Wien-bridge components as "plug-in" units.

DECLASSIFIED

SECRET

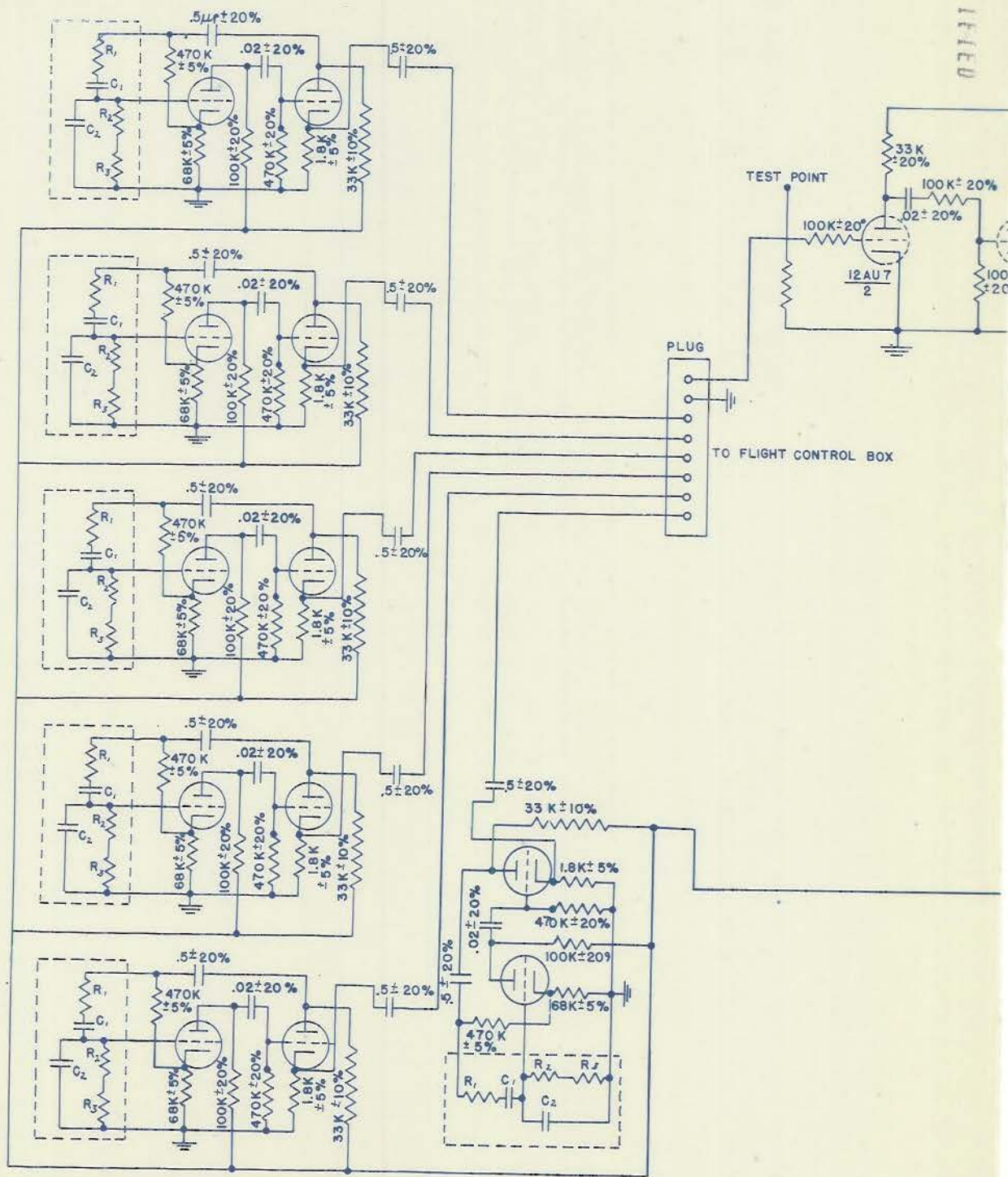
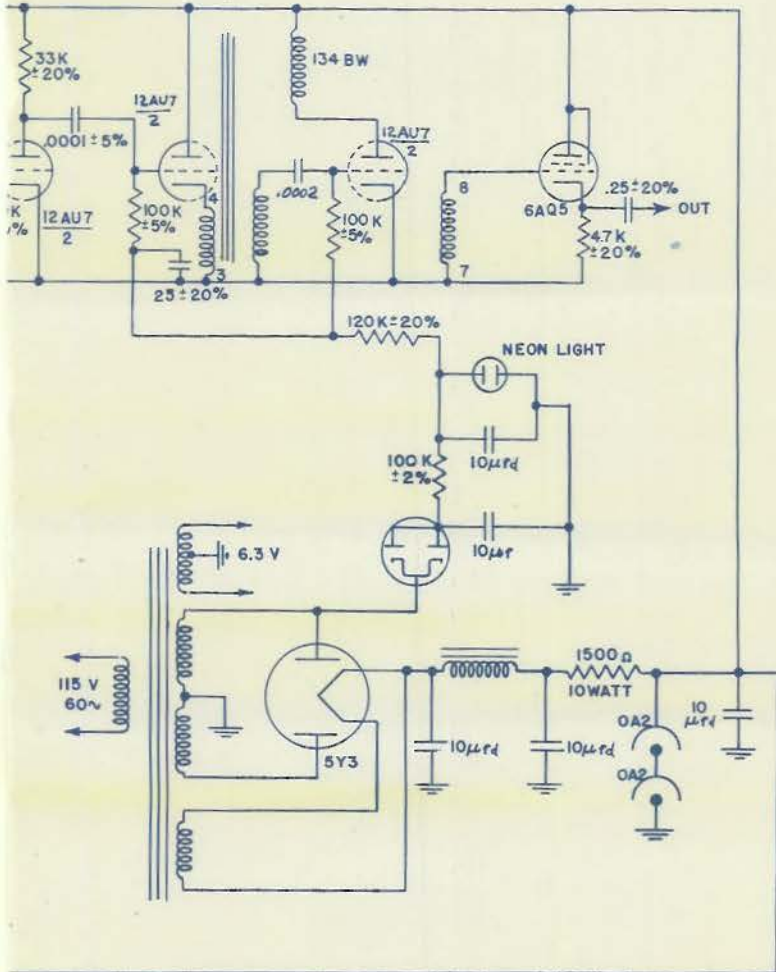


Fig. 4 - Coder for AN/DPW-2 (X1)



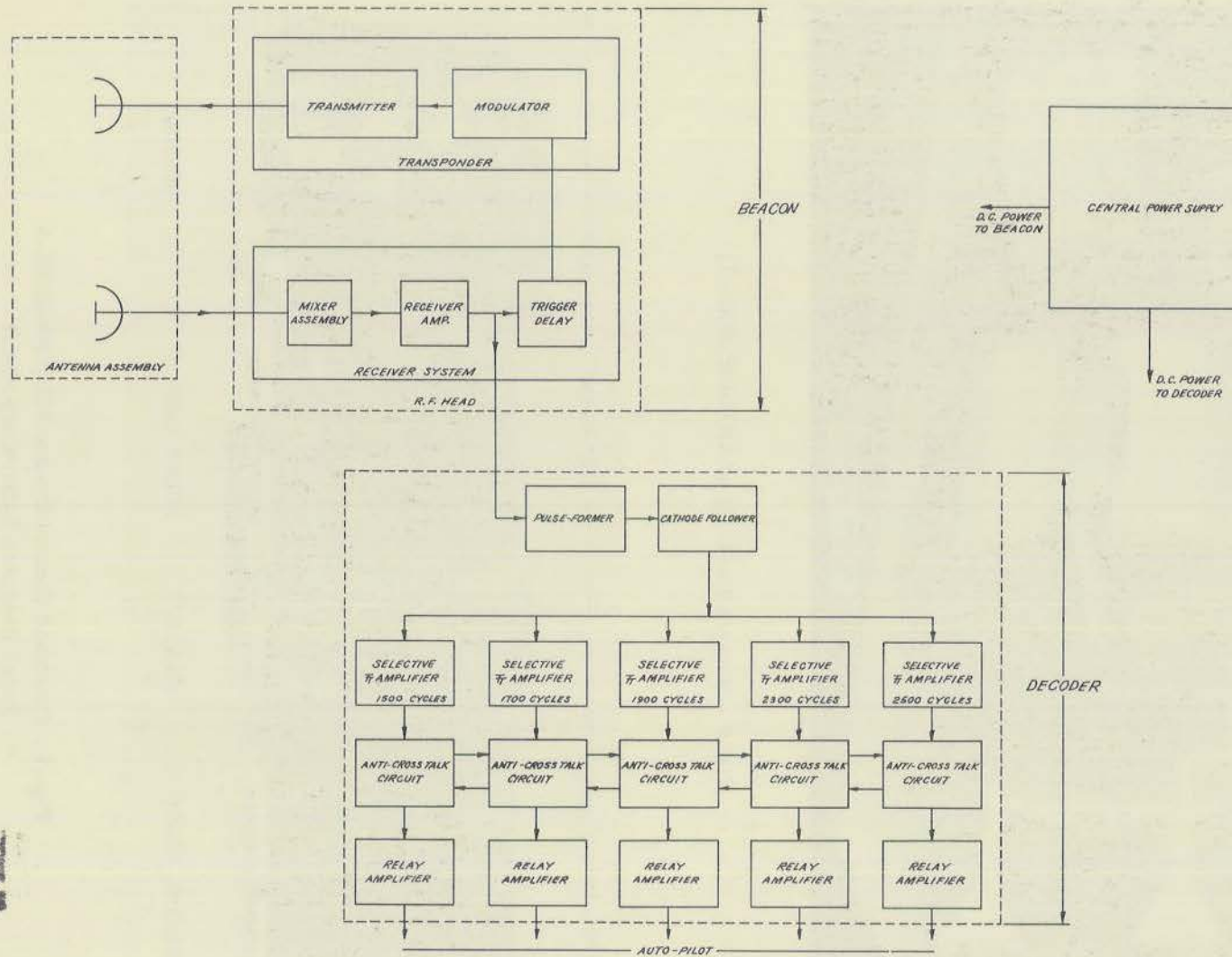
WIEN-BRIDGE COMPONENTS

F.K.C.	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	C <sub>1</sub>	C <sub>2</sub>
1.5	100KΩ 1%	20KΩ 1/5 W	90KΩ 1%	1060μF 1%	1060μF 1%
1.7	100K 1%	20K 1/5 W	90K 1%	935 1%	935 1%
1.9	100K 1%	20K 1/5 W	90K 1%	838 1%	838 1%
2.1	100K 1%	20K 1/5 W	90K 1%	758 1%	758 1%
2.3	100K 1%	20K 1/5 W	90K 1%	693 1%	693 1%
2.5	100K 1%	20K 1/5 W	90K 1%	637 1%	637 1%

N-1)

SECRET

SECRET



DECLASSIFIED

DECLASSIFIED

Fig. 5 - Block Diagram of Airborne System for Kingfisher "E" - AN/DPW-2(XN-1)

UNCLASSIFIED

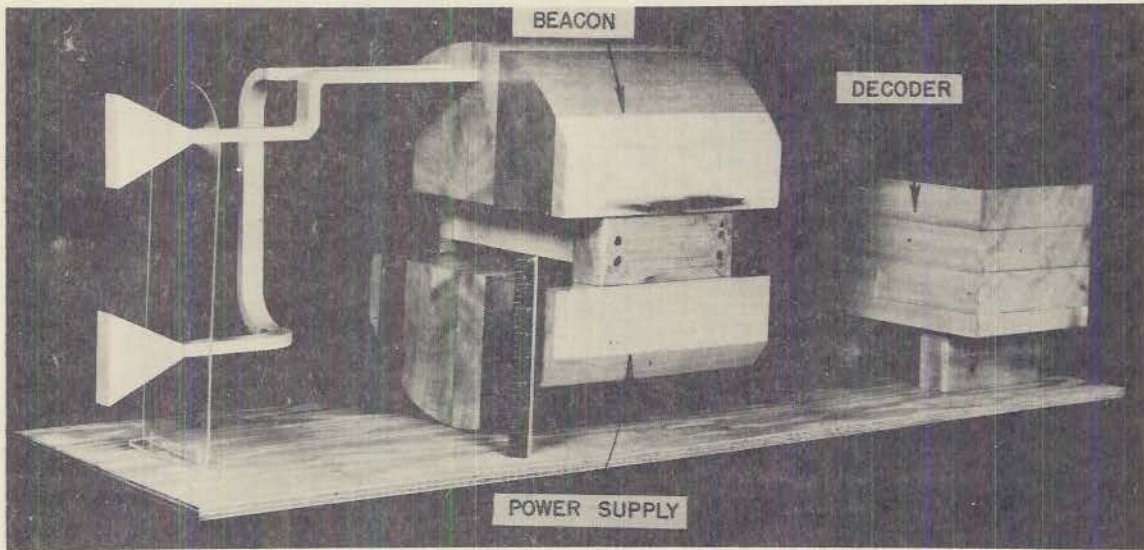


Fig. 6 - Wooden Mock-Up of AN/DPW-2(XN-1)

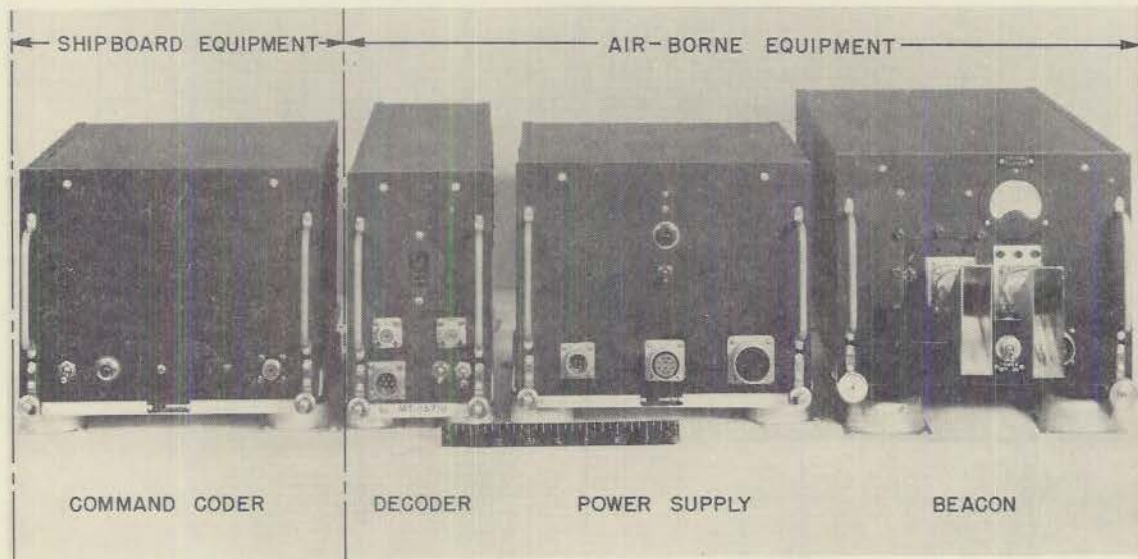
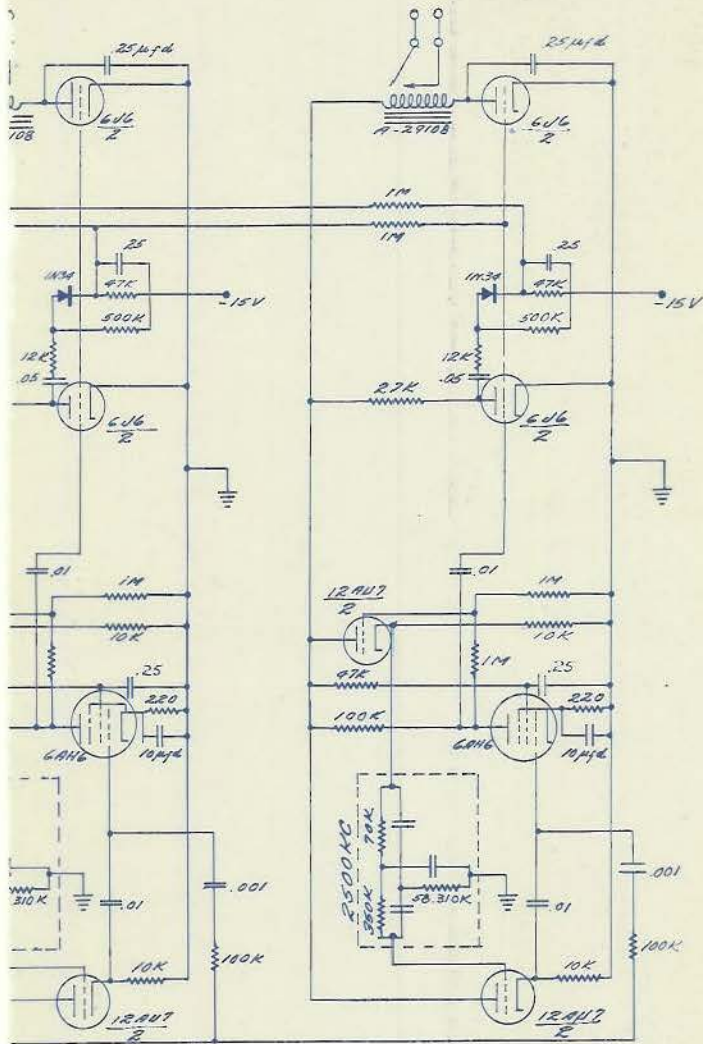


Fig. 7 - Command Control System AN/DPW-2(XN-1)  
Naval Research Laboratory Model





1)  
ign

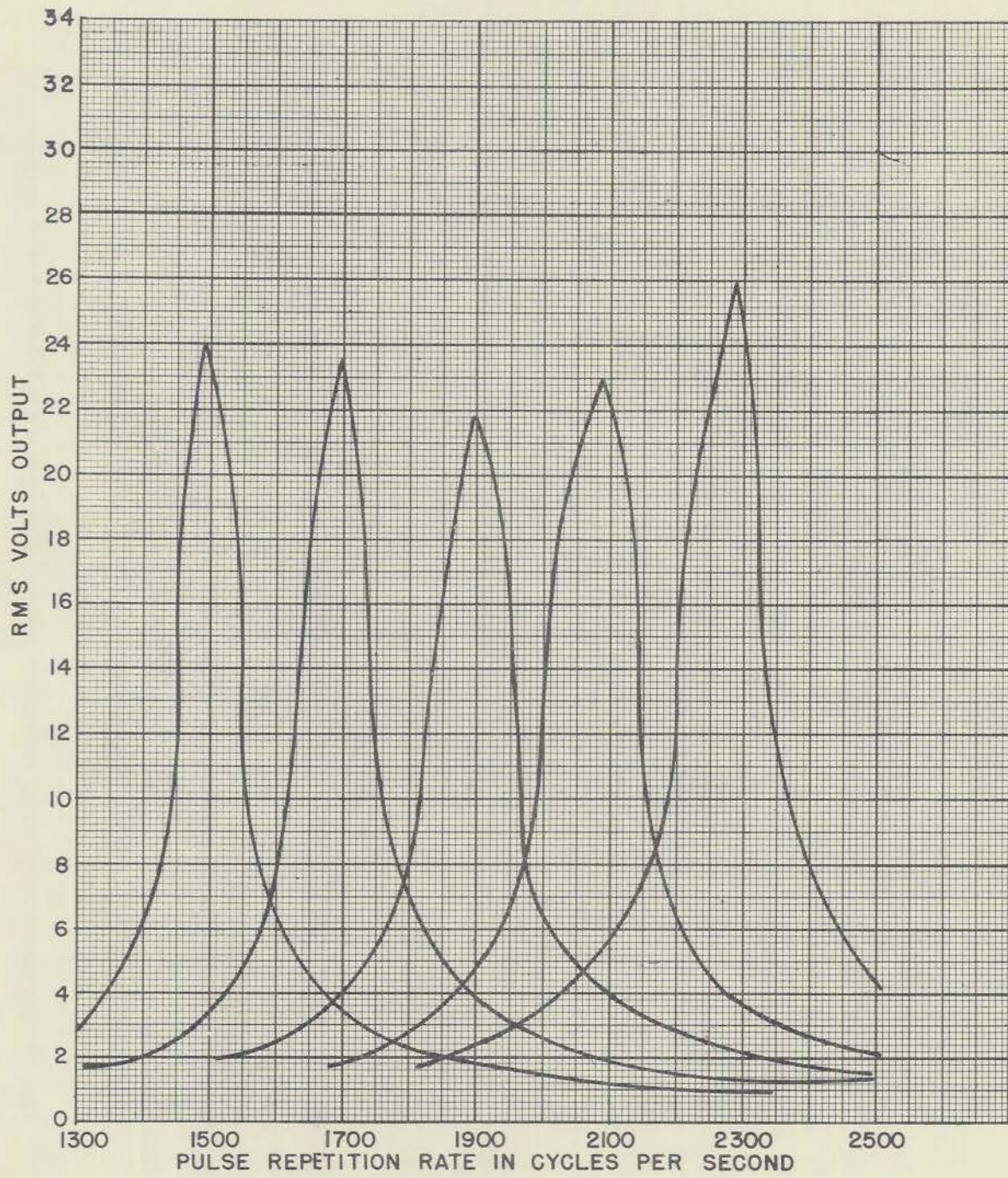


Fig. 9 - Characteristic Curves of Parallel-T Amplifier Circuits in Selector Unit



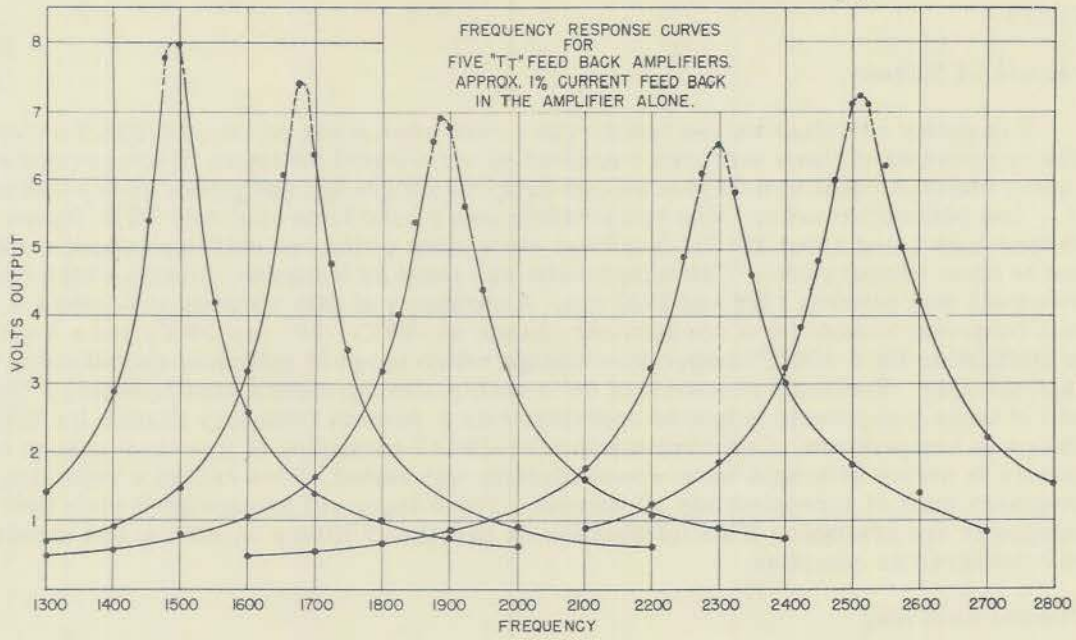


Fig. 11 - Model XA-III Decoder Frequency Response Curves

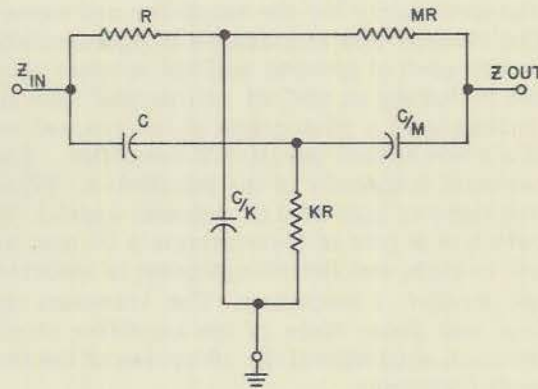
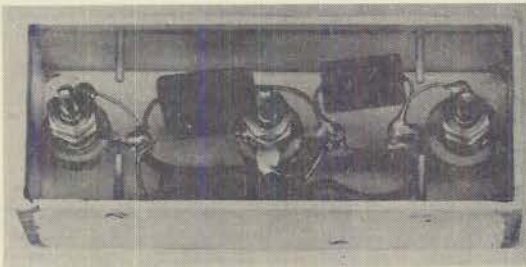


Fig. 12 - Parallel-T Components

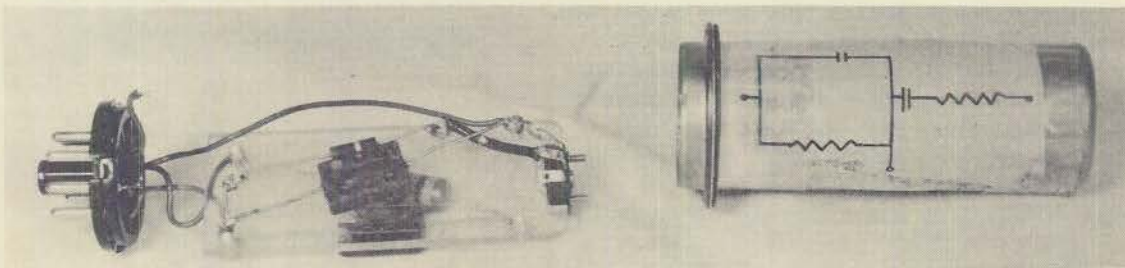


Fig. 13 - Adjustable Wein Bridge for Coder

## TESTS

## Parallel-T Filters

Frequency variation versus temperature runs were made on the parallel-T networks. The components of these networks consisted of wire-wound resistors of one percent accuracy (delta-R equal to 0.02 percent per degree centigrade); and silver mica condensers of  $\pm$  one percent accuracy. The temperature was varied from  $-50^{\circ}$  to  $+50^{\circ}$ C, (room temperature being about  $27^{\circ}$  C). Readings were taken at the two extreme temperatures and at room temperature. This information was taken on a number of units whose center frequency was between 1500 and 2500 cps. A summary of data obtained indicated a 2-percent frequency change for a temperature change of  $100^{\circ}$  C ( $-50^{\circ}$  to  $+50^{\circ}$ C) and a 2-db change in attenuation for a  $100^{\circ}$ C temperature change which is not of sufficient magnitude to be objectionable. Precision resistors of the metallic-film type were unsatisfactory. One unit of these components indicated approximately 8-percent frequency change for  $100^{\circ}$ C change in temperature. One compensated parallel-T consisting of 5 percent carbon resistors in series with each wire-wound resistor was tested. This caused a reduction in frequency shift of approximately 50 percent. These tests will be continued when time and manpower are available. This information on parallel-T filters is interim and should not be considered as complete.

## Channel Switching

The decoder was set up on the bench and the channels were switched at rates up to 100 cps. The 1900-cycle channel was switched at the above rates and the rise and decay times at the plate of the parallel-T amplifier were observed, since they would be one factor of internal delay in the equipment. It was determined that the transient rise or transient decay for the amplifier and associated filter was approximately 0.005 seconds. The channel was considered to operate satisfactorily without the relay up to 60 cps. The relays used at present will not operate above 20 cps. The speed at which the channels can be turned on and off will depend upon the quality of relays being used. Figure 14 is a tracing from a photograph of the channel response.  $S_1$  is the signal applied to the input of a conventional parallel-T amplifier. The frequency being applied is the same as the resonant frequency of the parallel-T. (Time increases to the right and each of the vertical fine lines is spaced 0.01 seconds apart.) The input signal  $S_1$  is being applied by means of a switch at a rate of approximately 50 cps; actually the switching rate is increasing from left to right and the 50-cps point is indicated.  $S_2$  is a recording of the output signal from the parallel-T amplifier. The transient rise time and decay time of the amplifier circuit are each approximately 10 cycles of the resonant frequency.

Some investigation has been made into the ring time of toroidal filters with Q's of sufficient magnitude to perform the same function as the parallel-T networks. Figure 15 is a photograph of the ring time of a filter incorporating two toroidal coils, capacity tuned and utilizing capacity coupling. This print was obtained by recording the output while switching the 1500-cps center frequency into the tuned circuit at a rate of 60 cps. This

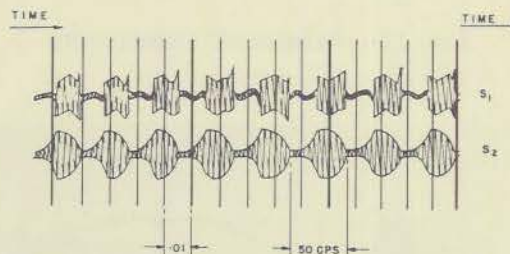


Fig. 14 - Channel Response of the 1900-Cycle Channel Showing Ring Time

record indicates a rise time of about 0.013 seconds and a decay time of about 0.013 seconds. The response curve of a toroidal band pass filter showing equipment and method used to obtain this curve will be shown later in Figure 19.

#### Parallel-T Amplifier Design Factors

Curves are shown in Figure 16 of parallel-T rejection filters used. The method of designing, constructing, and testing parallel-T rejection filters including their use in feedback circuits of amplifiers and discriminators will not be included in this interim report, however, the author would like to offer the references below.<sup>6</sup> At present the R and C components generally available are considered not practical for use in the parallel-T null network filter utilized in the Kingfisher "E" command control system.

The practical problems involved in designing of amplifiers and parallel-T networks are such that a considerable amount of work has yet to be done before a solution to the problem will be at hand. Regarding the problem of frequency shift caused by changes in temperature, calculations indicated that the frequency can be held constant over any temperature range by the use of components that are temperature compensating. That is, the capacitors and resistors should each have temperature coefficients of equal magnitude but of opposite sign. Thus any frequency variations caused by temperature changes in the resistive components will be cancelled by equal and opposite variation in the capacitive components. Figure 11 represents the frequency characteristics or gain characteristics of each of the parallel-T networks in the XB-III decoder unit. The variation in peak amplitudes indicated either a difference in the parallel-T networks or a variation in the gain of the amplifier circuits used. This irregularity is being investigated with expectations that it will be possible to design and to mass-produce this circuit in such a manner as to obtain uniform results. The XB-III decoder circuit schematic is shown in Figure 10.

#### Testing of Complete System

To bench-test the system including the command coder, command receiver, and command decoder, the radar was replaced by an X-band signal generator, and the command coder pulse output was used to trigger the signal generator. The radio link was replaced by an adjustable attenuator between the signal generator and the command receiver input. By observing the pulse-for-pulse response of the beacon and by switching channels either manually or automatically, the decoder relay operations were recorded. Extended bench tests over several weeks of operation indicated that the equipment was reliable but that some improvements were desirable to safeguard against breakdown.

<sup>6</sup> J. R. Tillman, W. E. 23, 281-286, Oct. 1946. L. Bowers, Electronics 20, 131-133, April 1947. Charles F. White, "Transfer characteristics of a bridged parallel-T network," NRL Report No. R-3167, Sept. 1947. H. S. McGaughan, Tele-Tech 6, 48-51 August, 1947.

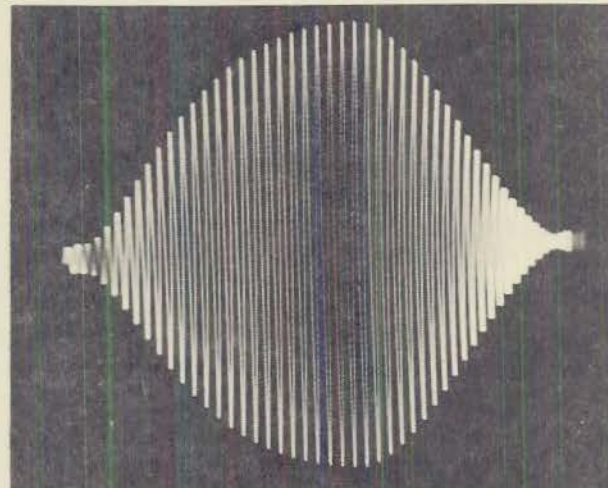


Fig. 15 - Ring Time of Toroidal Coils

Overcoupled L-C Circuit

$Q = 25$

Switching Rate - 60~

Frequency - 1500 cps

Rise Time - 0.013 sec.

Decay Time - 0.013 sec.

DECLASSIFIED

18

NAVAL RESEARCH LABORATORY

SECRET

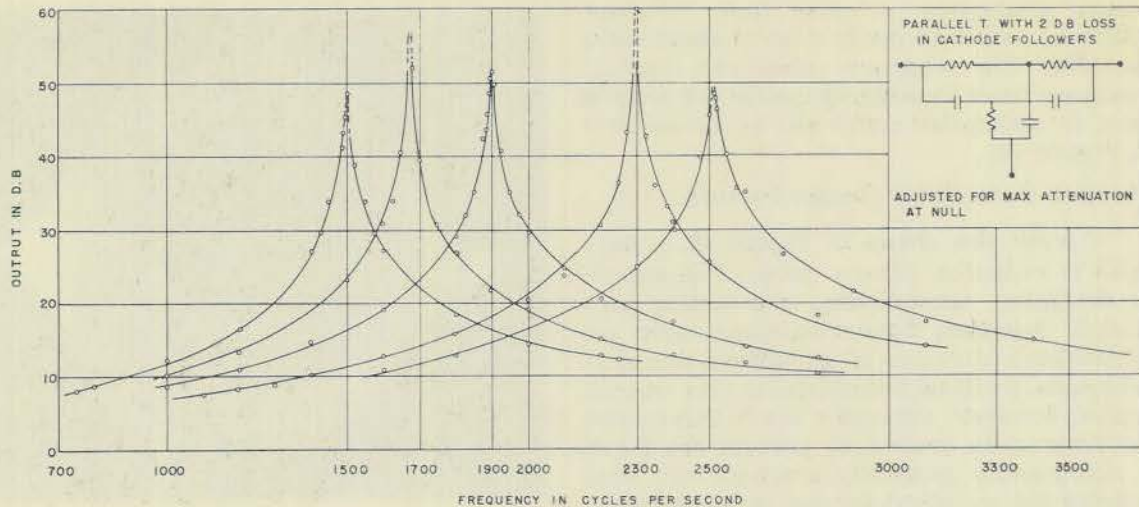


Fig. 16 - Parallel-T Null Network Characteristics

After completion of bench tests the equipment was moved to NAOTS, Chincoteague, Va. for installation in an SNB aircraft for flight tests. These tests consisted of flying out on the radar beam to given ranges to determine that the command control equipment responded to the channel intelligence being sent throughout the entire length of the flight. The results of the flights were very favorable in that the decoder performed satisfactorily, and, after a few minor changes were made in the power supply and in the beacon, the complete equipment proved to be reliable from day to day during flight tests.

Radar tracking data taken on the Mk 25 and on the HSL radar indicated considerable improvement in target tracking since the radar was tracking a more nearly point source. At low elevation over water some trouble was experienced with reflection. This should not have any detrimental effect on the missile since the radar is expected to track in bearing only. Tracking in azimuth was satisfactory.

Tracking data on beacon and on echo were taken for comparison purposes.<sup>7</sup> Photographs of the NRL equipment installed in an SNB-1 at Chincoteague, Va. are shown in Figures 17 and 18. Flight tests were made to check the beacon operation and the radar tracking. Although detailed data are not discussed here, the performance was entirely satisfactory. The flight test used the High-Speed Lobing (HSL) radar at NRL and the Mark 25 radar at CBA.

The coder was operated by a mechanical switch controlled by the radar range information in such a way that the channel chosen was independent of this information. Lights energized by the decoder channel outputs were photographed as a record of the system operation.

#### CIRCUITS CONSIDERED BUT NOT USED

Consideration has been given to a proportional control command system accomplished by frequency modulating the radar repetition rate. This would enable the simultaneous operation

<sup>7</sup> The tracking data was published in the July Quarterly Report of the National Bureau of Standards on the Kingfisher Problem.

DECLASSIFIED

SECRET

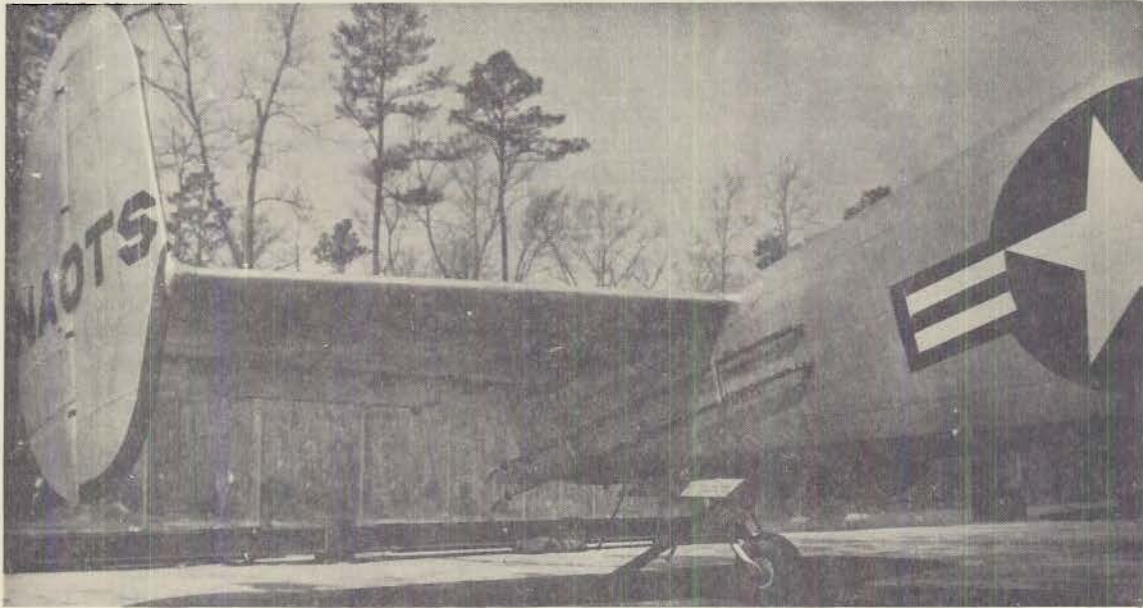


Fig. 17 - Antenna Installation on an SNB-1 Aircraft Used in Flight-Testing AN/DPW-2(XN-1) Equipment

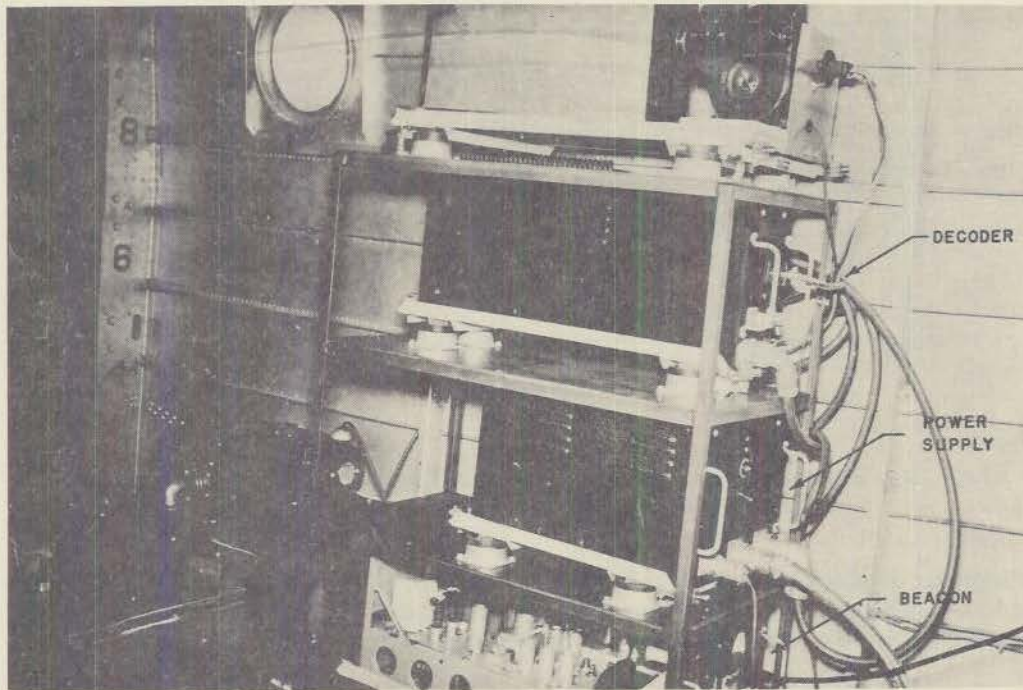


Fig. 18 - AN/DPW-2(XN-1) Installation in an SNB-1 Aircraft

of two channels and would limit to two the number of "on-off" channels that could be used. One proportional control channel would allow the addition of three "on-off" channels. At present, however, there seems to be no demand for proportional control command equipment in the Kingfisher "E" missile since the system has been limited to time-division between channels, and to simple "on-off" control. Several types of selective circuits have been considered using the parallel-T null network; these include the circuits shown in Figures 9 and 11 which are parallel-T feedback amplifiers.

Also considered was the L-C selective circuit using inductive toroidal coils in a double-tuned circuit and capacity coupling as shown in Figure 19. Various values of Q

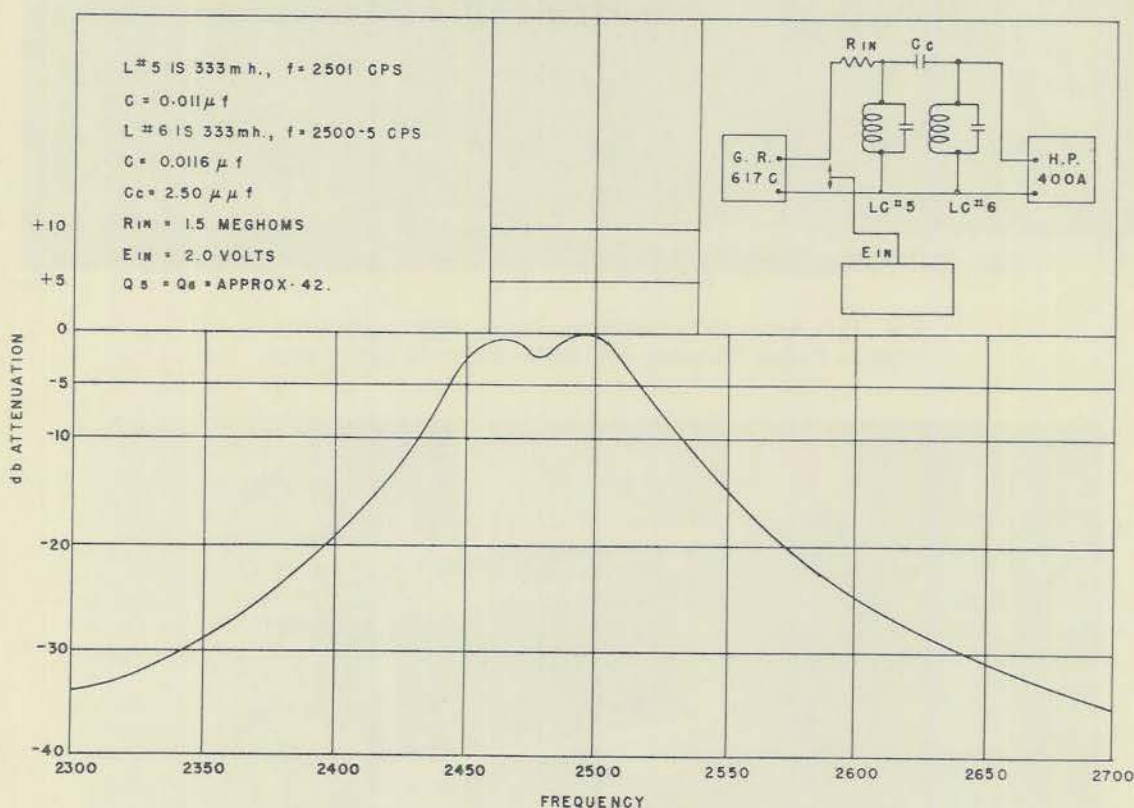


Fig. 19 - Toroidal Transformer Response Curve Using Capacity Coupling  
(The curve is plotted neglecting insertion losses)

were obtained. A plot of one typical response curve is also shown in Figure 19. Figure 15 is a photo of its ring time. These are the characteristics which determine the suitability of the L-C circuits for the Kingfisher "E" program.

IMPROVEMENTS MADE

Comparison of Figure 8 and Figure 10 will indicate two changes; one is that of using a gas-tube-relay amplifier to save d-c power requirements, and the other is that of using

relay contacts to disable adjacent channels rather than using the electronic circuit shown in Figure 8.

#### CONCLUSIONS

Since this command system has been operating satisfactorily, on such tests as have been made, without interfering with the automatic tracking ability of the Radar, Mk 25, it may be concluded that the modified Hornet guiding system will probably prove satisfactory for use with the Kingfisher "E" missile. The results of tests made on a number of the individual circuits involved in the command system indicate that these circuits are practical for production purposes.

#### RECOMMENDATIONS

The following additional work is recommended before the Kingfisher "E" problem is terminated at the Naval Research Laboratory: (a) a study to continue a comparison of L-C versus R-C networks as the frequency selective elements in the command system, (b) subminiaturization of the system into its smallest possible form, (c) investigation of miniature power supplies for use in the system, and (d) continued investigation into the availability or development of precision components that will operate satisfactorily over the desired temperature range ( $-50^{\circ}$  to  $+85^{\circ}$  C).

The system could be reduced in size by sub-miniaturizing, but this would require from six to twelve months depending upon the manpower available. The temperature problem associated with the filter networks may be solved in the very near future.

#### ACKNOWLEDGMENTS

The author would like to acknowledge the assistance given by Mr. F. E. Huggins, Mr. R. R. Zirm, Mr. S. Levine, Mr. K. O. Kelly and Mr. A. Loebel for the development and testing of this equipment. The Laboratory is indebted to NAOTS (Naval Aviation Ordnance Test Station) at Chincoteague, Va. for the excellent installation and flight-testing facilities being furnished for this work.

\* \* \*



Faint, illegible text, possibly bleed-through from the reverse side of the page.

Faint, illegible text, possibly bleed-through from the reverse side of the page.

Faint, illegible text, possibly bleed-through from the reverse side of the page.

Faint, illegible text, possibly bleed-through from the reverse side of the page.

Faint, illegible text, possibly bleed-through from the reverse side of the page.

Faint, illegible text, possibly bleed-through from the reverse side of the page.

