DECLASSIFIED

[redacted] UNCLASSIFIED

NRL REPORT 3620

FR-3620

DEVELOPMENT OF A 1000-MC BROADBAND CRYSTAL DETECTOR

DECLASSIFIED by NRL Contract Declassification Team
Date: 24 JAN 2017
Reviewer's name: [redacted]
Declassification authority: NAVY DECLASS GUIDE/NAVY DECLASS MANUAL, 11 DEC 2012

CLASSIFICATION CHANGED TO UNCLASSIFIED
BY AUTHORITY OF Sp4, SecN Dir 5200.10
Reference Authority
ON 5-15-62
(DATE)
Susie Jean Lambert
Signature of Custodian

DISTRIBUTION STATEMENT A APPLIES
Further distribution authorized by UNLIMITED only.

NAVAL RESEARCH LABORATORY

WASHINGTON, D.C.

DECLASSIFIED

[redacted]

UNCLASSIFIED [redacted]

[redacted] DECLASSIFIED

NRL REPORT 3620

DEVELOPMENT OF A 1000-MC BROADBAND CRYSTAL DETECTOR

Ralph M. Gran

26 January 1950

Approved by:

Mr. H. O. Lorenzen, Head, Countermeasures Branch
Mr. L. A. Gebhard, Superintendent, Radio Division II

NAVAL RESEARCH LABORATORY
CAPTAIN F. R. FURTH, USN, DIRECTOR
WASHINGTON, D.C.

[redacted] DECLASSIFIED

DISTRIBUTION

BuShips	
Attn: Code 838	10
BuAer	
Attn: Code EL-91	2
Attn: Code TD-4	2
BuOrd	
Attn: Code Re-9	2
CNO	
Attn: Code Op-413B2	6
Attn: Code Op-341D	1
Attn: Code Op-413C3	1
Attn: Code Op-201X	2
Attn: Code Op-202L	2
ONR	
Attn: Code 470	2
CO, ONR, Boston	1
CO, NADS, Johnsville	2
Dir., USNEL	2
CDR., USNOTS	
Attn: Reports Unit	2
CDR., USNOL	1
ComOpDevFor	1
Supt., USNPGS	1
CO, Fleet Training Center, Norfolk	1
CO, C.I.C., Team Training Center, Boston	1
CO, Fleet Training Center, Newport	1
CO, USN School of Electronics, Great Lakes, Ill.	
Attn: Lt. J. J. Bartko	2
OCSigO	
Attn: Ch. Eng. & Tech. Div., SIGGE-01	1
Attn: SIGTM-S	1
CO, SCEL	
Attn: Dir. of Eng.	2
Ch. of Staff, USAF	
Attn: AFOAE	2
Attn: AFMEN-2	1

[redacted]

DISTRIBUTION (Cont.)

BAGR, CD, Wright-Patterson AFB	
Attn: CADO-D1	1
CG, AMC, Wright-Patterson AFB	
Attn: Eng. Div., Electronics Subdiv., MCREEO-2	1
Attn: Aircraft Rad. Lab., Advanced Dev. Branch	1
CO, Watson Labs., AMC, Red Bank	
Attn: ENR	1
CO, Air Force Cambridge Res. Labs	
Attn: ERRS	1
CINCNELM	
Attn: RCM Officer	1
CG, HQ, SAC, Offutt AFB	
Attn: Electronics Section	2
HQ, 311th Air Div., Barksdale AFB, Shreveport, La.	
Attn: Deputy Chief of Staff Operations	2
Dir., NBS	
Attn: CRPL	1
RDB	
Attn: Library	2
Attn: Navy Secretary	1
Naval Res. Sec., Science Div., Library of Congress	
Attn: Mr. J. H. Heald	2

[redacted]

CONTENTS

ABSTRACT

A broadband crystal detector unit has been developed primarily for use in a system providing a visual presentation of amplitude response curves for a 1000-Mc amplifier. The output response of the detector is constant to within ± 0.15 db over the range of 950-1070 Mc. The maximum input SWR over this range is 0.75 db.

PROBLEM STATUS

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

AUTHORIZATION

NRL Problem RO6-07R (BuShips S-1255X-C)

NE 071-211

DEVELOPMENT OF A 1000-MC BROADBAND CRYSTAL DETECTOR

INTRODUCTION

In the investigation of 1000-Mc grounded-grid coaxial amplifiers[1] it was necessary to acquire a considerable amount of information for the pass band amplitude response curves. The response data were obtained by the slow and tedious "point-by-point" substitution method. It was realized that a much faster means of acquiring data was essential for the satisfactory progress of the investigation.

A frequency-sweeping oscillator system appeared to be the only method to give a rapid visual indication of the effect of amplifier adjustments on the amplifier response. This system consists of a 1000-Mc frequency-modulated oscillator of essentially constant amplitude output, the 1000-Mc amplifier under test, a broadband crystal detector, and a d-c amplifier connected directly to the vertical plates of an oscilloscope. The horizontal sweep of the oscilloscope is synchronized with the frequency sweep of the oscillator.

The r-f output of the oscillator is held constant within ± 1db by a d-c control amplifier which samples the r-f output and regulates the plate voltage of the oscillator tube. As the r-f input to the amplifier under test is essentially constant, it is desirable that the detector portion of the system also have an essentially constant response.

The assumed requirements of such a crystal detector unit are that it have an input SWR of less than 1 db and an output response practically independent of frequency over a 100-Mc range centered at 1000 Mc. Such a unit was not known to exist, so it was necessary to develop one. This report is concerned with the development of the desired unit.

DEVELOPMENT

The first broadband crystal detector unit constructed consisted of a resonant coaxial cavity terminated by a 1N21B crystal. It was designed with two adjustments. One adjustment varied the cavity length for tuning, and the other was a movable contactor on the center conductor for input impedance matching. The cavity acted as a transformer and gave a voltage gain. However, when tested the unit did not give the required SWR of less than 1 db over the 100-Mc range centered at 1000 Mc.

In order for the detector unit to have a low SWR over a wide frequency range, the input impedance must remain substantially constant, resistive, and equal to the characteristic impedance of the cable connected to it. This condition may be obtained if the detector unit consists of a coaxial line of Z_0 terminated with a padded crystal having a resistive impedance as close as practicable to Z_0.

A 1N21B crystal with a high inverse ratio was selected to be used in the development of the new unit. Two thirds of the small tip was removed in an attempt to reduce the reactance of the crystal holder. Measurements of the impedance of this crystal at 1000 Mc were conducted in a plain mount consisting of a 50-ohm coaxial line terminated by the crystal. Calculations based on measurements obtained by the slotted-line method determined the impedance to be approximately 20-j204 ohms with the d-c terminals of the crystal open-circuited. It was estimated that, if the crystal were shunted by a 50-ohm resistance, the equivalent impedance would become approximately 47.5 $\angle -14^\circ$ ohms. As the final unit was intended to work into a very high resistance, all future tests were made with an open d-c circuit as the crystal d-c load.

[1] Weedman, W. F., "Development of a 1000-Mc Intermediate Frequency Amplifier." NRL Report No. 3531 (Confidential). Being published.

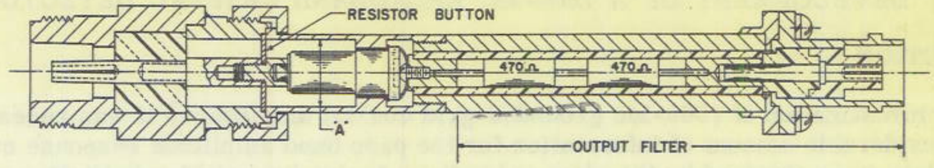

Fig. 1 Sectional View of Crystal Detector Unit

A crystal holder was designed incorporating the modified crystal, a shunt disk resistor, and an output filter as shown in Figure 1. The first shunting resistors were circular resistive buttons made from 800-ohm per square resistive bakelite with a ring of silver paint brushed on the outer edge of the carbon-coated surface. The resistance of the button was determined by the width of the ring.

This method for establishing intimate contact with the button did not prove satisfactory. It was necessary to remove some of the paint for small variation of resistance, and this action damaged the carbon surface. Also, the paint had a tendency to crack under pressure when the button was assembled in the unit.

A new series of buttons was fabricated, using 400-ohms per square resistive bakelite. The d-c resistance was now in the range of 40 to 60 ohms. The resistance of the buttons with too low a value was raised by rubbing the carbon side on a flat surface of crocus paper.

Measurements made with a variety of buttons in the crystal holder, shown in Figure 1, indicated that the impedance mismatch of the holder at 1000 Mc was too high. The minimum SWR was 3.5 db, a high value perhaps due to irregularities in the diameter of the center conductor such as the 1N21B tip, the lead, the bead, and the catwhisker. Attempts to reduce the SWR were made by changing the dimension A of Figure 1. Each increase or decrease was tested with different values of resistor buttons. The optimum result was obtained with dimension A equal to 0.375 inch and a button of 47 ohms d-c resistance, but this combination still gave an excessive minimum SWR of 2.95 db.

The possibility of compensating for the mismatch of the crystal holder unit with a quarter-wave impedance-matching section was considered advisable. Calculation of the impedance of the crystal unit, based on measurements obtained by the slotted-line method, determined the dimensions of a quarter-wave section and its distance from the button. It was constructed and inserted in the unit as shown in Figure 2. The matching then became a function of three variables:

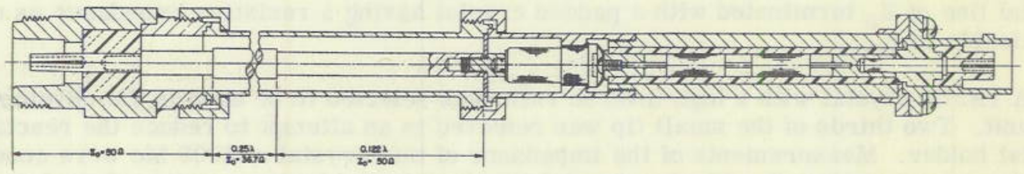

Fig. 2 Sectional View of Final Crystal Detector Unit

(1) the outside diameter of the center conductor of the quarter-wave section, (2) the length of the center conductor of the quarter-wave section, and (3) the distance of the quarter-wave section from the button. In the final model it was found expedient to vary the resistance of the button also.

The first measurements of the SWR versus frequency showed that the minimum SWR occurred at too low a frequency. It was indicated that the quarter-wave section probably was not spaced the correct distance from the button. For quick location of the best placement, a temporary center conductor was constructed with a movable sleeve to eliminate the necessity of remaking the quarter-wave section for each trial. Measurements were made using the combination of three variables of sleeve placement, sleeve diameter, and button resistance.

A very low minimum VSWR of 1.04 (0.4 db) was obtained with one of the combinations. Because of possible changes of the sleeve contacts with time, a solid center conductor was constructed with the quarter-wave section located in the position determined by the sliding sleeve. Measurements with the solid center conductor revealed that the SWR was now too high. Thus it appeared that a center conductor with a sliding sleeve could not be replaced by a solid conductor with the quarter-wave section in the same location. However, it was found that, when a button having a new optimum value was employed, a very low SWR was again obtained. Another center conductor was made with the quarter-wave section located a half inch closer to the button. This conductor when used with the optimum value of resistor gave practically the same bandwidth and SWR as the previous combination. From these results it may be assumed that a change in reactance caused by displacement of the quarter-wave section can be very nearly counteracted by a change in impedance of the padded crystal, or vice versa.

Another series of measurements was made with a 5% shorter quarter-wave section, but this made the SWR much too high. All following measurements were limited to the original length.

It was found that, when the unit was opened at the button and reassembled with the same button, it was usually impossible to measure the same values of SWR and impedance. Although the d-c resistance remained the same, there may have been a change in reactance due to pressure on different places of the button. All dimensional changes in the unit required opening at the resistor button, and it was not certain whether the variations in results were due to the dimensional changes or to a deviation of button impedance. It can be seen that, after a certain point, success was entirely dependent on the cut-and-try method. When a satisfactory result was attained, the unit was sealed to prevent further opening.

Since this unit was designed around a particular crystal, a replacement crystal may require a completely new design.

CHARACTERISTICS OF THE FINAL MODEL

After considerable experimentation an acceptable crystal detector unit was developed. The assembled unit is shown in Figure 3. It has a maximum input VSWR of 1.09 (0.75 db) over the

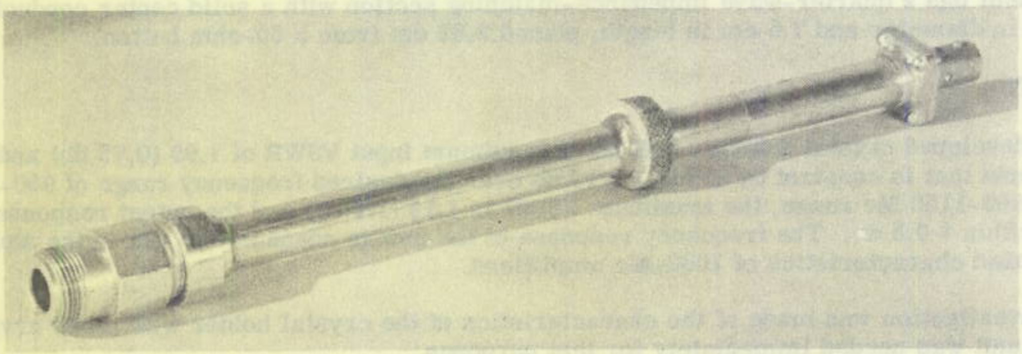

Fig. 3 Crystal Detector Unit

range of 950-1070 Mc. The VSWR vs frequency is plotted in Figure 4. The amplitude versus frequency response of the unit is presented in Figure 5, where the crystal detector output voltage,

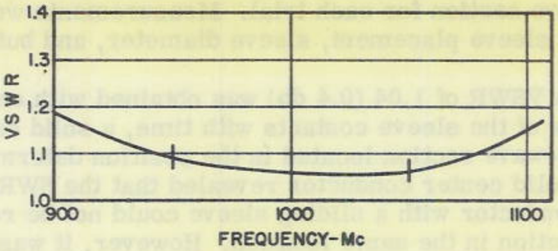

Fig. 4 Crystal Detector
VSWR vs Frequency

amplified 2500 times by a constant-gain d-c amplifier, is plotted versus frequency for three levels of r-f input voltage. The long-line effect is quite evident above 1250 Mc. This emphasizes the necessity of a low SWR requirement for the crystal detector unit.

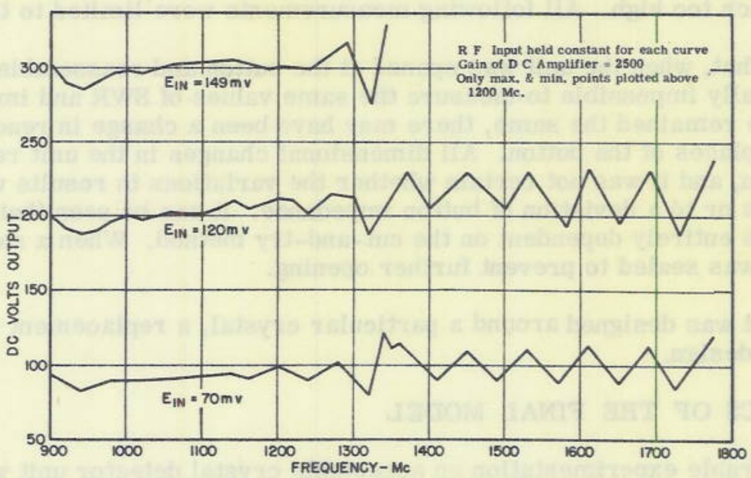

Fig. 5 Amplified D-C Output of Detector vs Frequency

The unit has a quarter-wave impedance-matching section with a solid center conductor of 0.515 cm in diameter and 7.5 cm in length, placed 3.66 cm from a 60-ohm button.

SUMMARY

The developed crystal detector unit has a maximum input VSWR of 1.09 (0.75 db) and an output response that is constant to within ± 0.15 db over the desired frequency range of 950-1070 Mc. Over the 900-1150 Mc range, the maximum VSWR is 1.19 (1.5 db) and the output response is constant to within ± 0.5 db. The frequency response of the unit is adequate for use in the study of the pass band characteristics of 1000-Mc amplifiers.

No investigation was made of the characteristics of the crystal holder with other crystals since the unit was needed immediately for test purposes.

ACKNOWLEDGMENT

The author wishes to acknowledge the aid of Mr. Henry K. Weidemann for his guidance during development.

* * *

[redacted]

NAVY-DPPO PRNC. WASH., D.C.