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Pulfer, J. K.

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RADIO AND ELECTRICAL ENGINEERING DIVISION

A RESISTIVELY TERMINATED BROADBAND COAXIAL CRYSTAL MOUNT

J. K. PULFER

OTTAWA

OCTOBER 1955

ABSTRACT

Development of a low standing-wave ratio coaxial crystal mount for use in the frequency band from 1000 to 6000 megacycles is described. A low level standing-wave ratio of less than 2 to 1 was attained over the entire band using a built-in 50-ohm terminating resistor and type-1N263 germanium crystals. Sensitivity under normal operating conditions varies from zero to four db below that of a typical commercially manufactured crystal mount.

CONTENTS

TEXT

FIGURES

GRAPHS

6. Sensitivity vs. Frequency Using type-1N263 and 1N23B Crystals in type-A and NRC MK III Mounts.

7. VSWR vs. Frequency for the NRC MK II and MK III Mounts using type-1N23B and 1N263 Crystals.

8. Sensitivity Distribution of 20 type-1N263 Crystals in a MK III Mount at 4000 Mc.

9. Sensitivity Distribution of 50 type-1N23B Crystals in a type-A Mount at 5500 Mc.

A RESISTIVELY TERMINATED BROADBAND COAXIAL CRYSTAL MOUNT

- J.K. Pulfer -

INTRODUCTION

Microwave impedance bridges and standing-wave ratio plotters often require two or more broadband crystal detectors which must track in sensitivity over a wide band of frequencies. In such a device, low standing-wave ratio at the crystal mount is essential, as well as maximum sensitivity, since any power reflected from the crystal would be reflected again by other parts of the circuit and cause multiple resonances.

With presently available video crystals, the radio-frequency input impedance varies widely with frequency, and a match over the range of 1000 to 6000 megacycles would involve a complicated reactive matching network. Such a network of stubs would require very close mechanical tolerances in construction, and also close tolerances in the electrical properties of the crystals used, if good tracking were to be obtained.

Tests made on a large number of type-1N23B crystals in a typical commercial mount (henceforth referred to as a "type-A" mount), have shown that radio-frequency impedance and the resulting sensitivity differ widely from crystal to crystal (see "Performance" P. 3). A maximum voltage standing-wave ratio of 26 to 1 was measured with a type-A mount, representing 85.8% reflected power. A simple calculation shows that resistive padding ahead of the crystal will lower the voltage standing-wave ratio to 2 to 1 with an additional loss of 5 db. Considerably less loss will result if resistive matching is used. Since the radio-frequency input impedance of a crystal is much higher than 50-ohms for most of the frequency range, a partial match can be obtained by placing a 50-ohm resistor in parallel with the crystal. This will also swamp large variations in crystal properties with the result that tracking is a much simpler problem. A crystal mount based on this idea was developed and tested, and has proven satisfactory.

GENERAL DESCRIPTION

Available components were used, where possible, in the development of the crystal mount. The basic elements are a type UG-21D/U male cable connector, and an "NRC Mk. II" crystal cap. The cable connector was subjected to the following modifications:

1) The center pin and its insulating support are removed, and replaced by a new center pin with polystyrene as the insulating material. The support is made a press fit into the connector, and the center pin pressed into the support. The new center pin is made with a slotted cup to accept the small end of a type-1N23 or similar crystal. A dimensioned sketch of the pin and support is shown in Fig. 1.

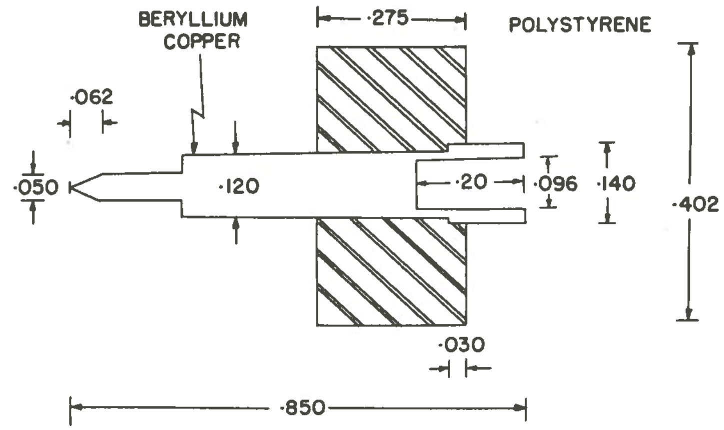


FIG. 1 CENTER PIN AND POLYSTYRENE SUPPORT

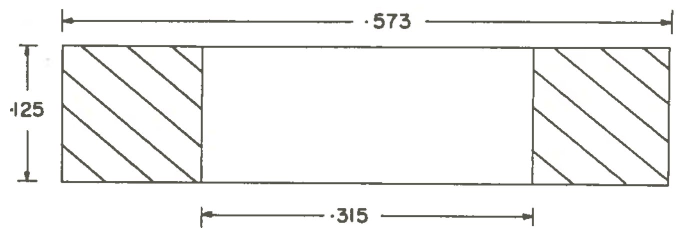


FIG. 2 BRASS RING

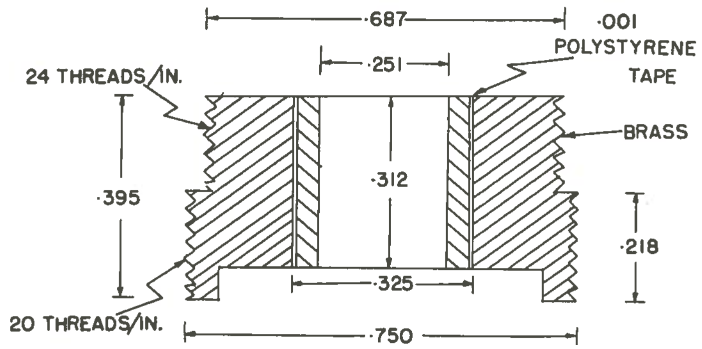


FIG. 3 DETAIL OF R.F. BYPASS PLUG
(All Dimensions In Inches)

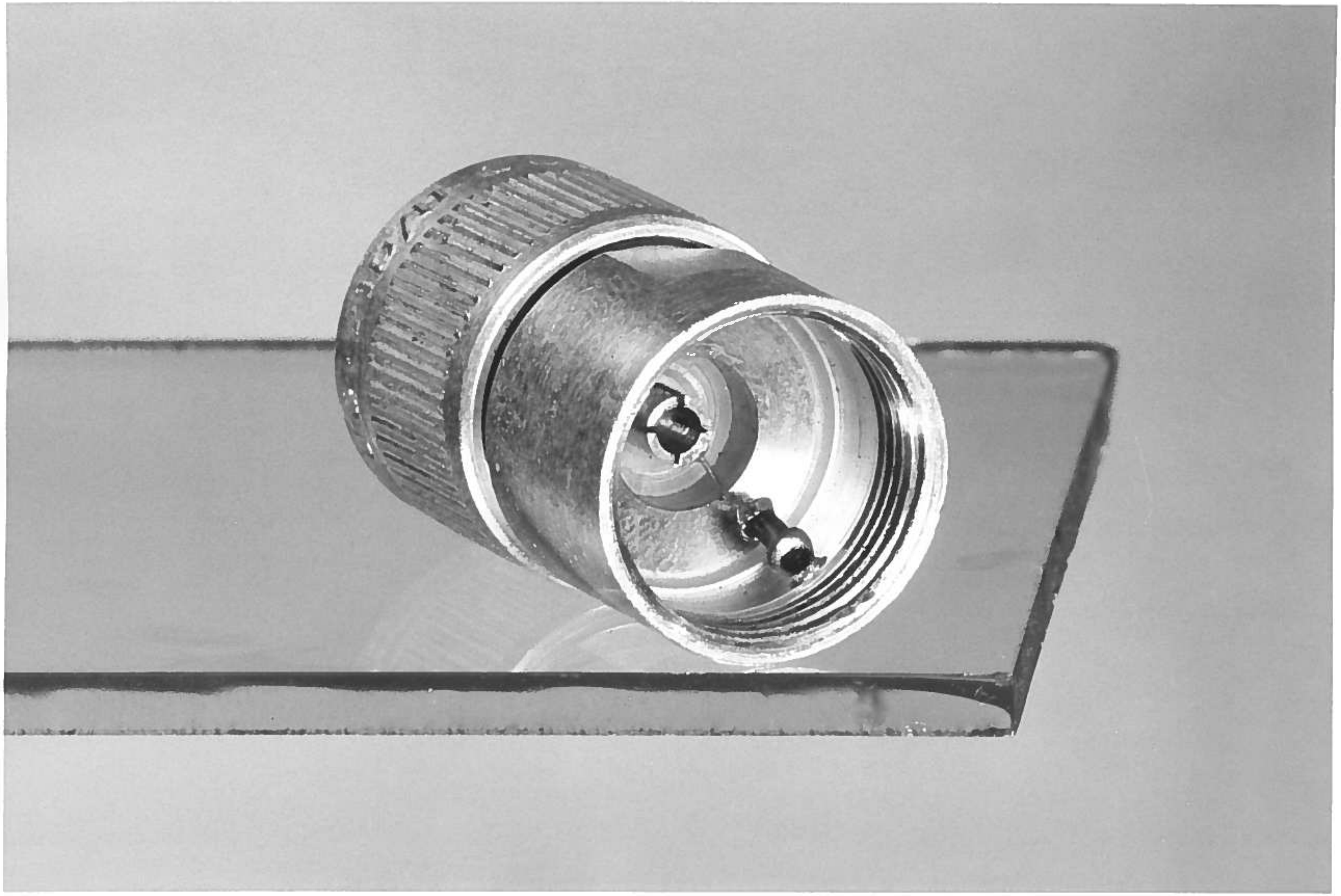


FIG. 4 BROADBAND COAXIAL CRYSTAL MOUNT
Interior Showing Method of Mounting Terminating Resistor

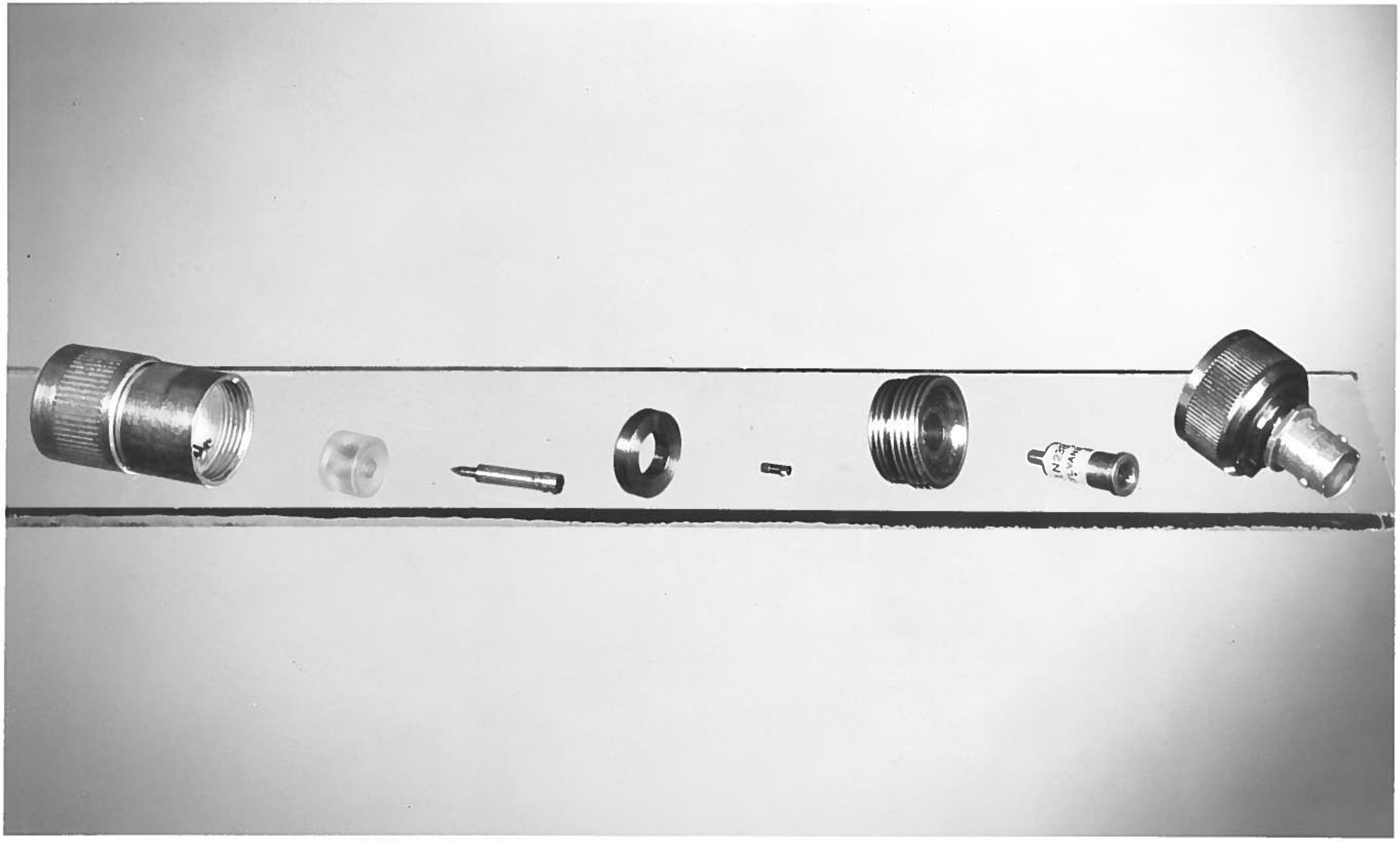


FIG. 5 BROADBAND COAXIAL CRYSTAL MOUNT
Exploded View

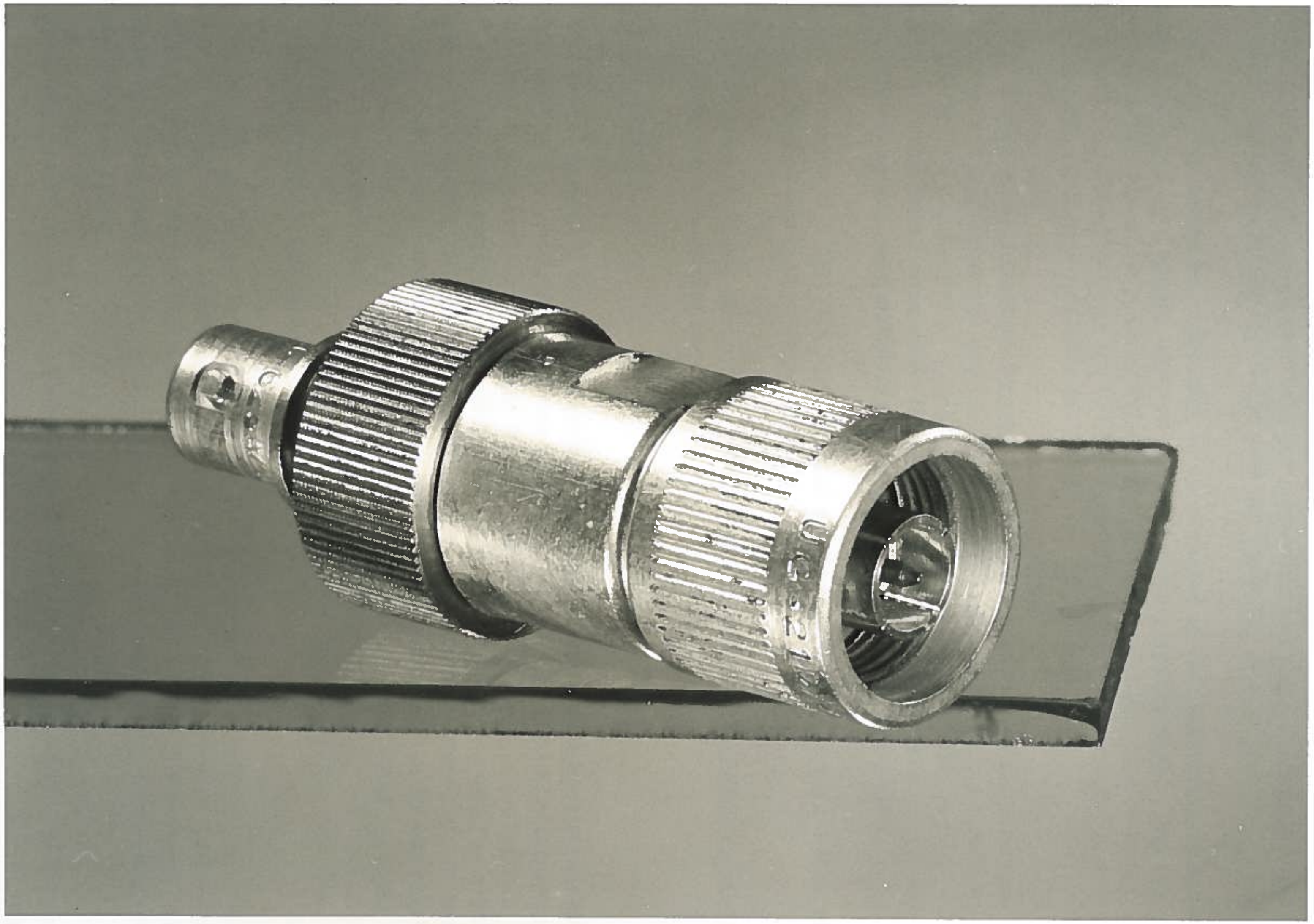


FIG. 6 BROADBAND COAXIAL CRYSTAL MOUNT (assembled)

2) A brass ring is pressed into the connector to extend the small diameter of the outer conductor to the top of the new pin (see Fig. 2).

3) A radio-frequency capacitor is constructed of two concentric cylinders of brass separated by a single layer of 0.001-inch polystyrene tape. The top of the crystal is fitted into the inside of the inner cylinder, and the outside of the outer cylinder is threaded into the wall of the type UG-21D/U connector. A dimensioned sketch of the capacitor is shown in Fig. 3.

4) A type-R063 Telewave 50-ohm resistor, equipped with short copper lead wires, is soldered from the cup on the end of the center pin to the inside wall of the type UG-21D/U connector at a point adjacent to the center of the crystal, as shown in Fig. 4. The latter connection is made by drilling a small hole in the wall of the outer conductor, and soldering the resistor lead from the outside.

5) A standard "NRC Mk. II" crystal cap is threaded on to the outside of the extended part of the bypass capacitor.

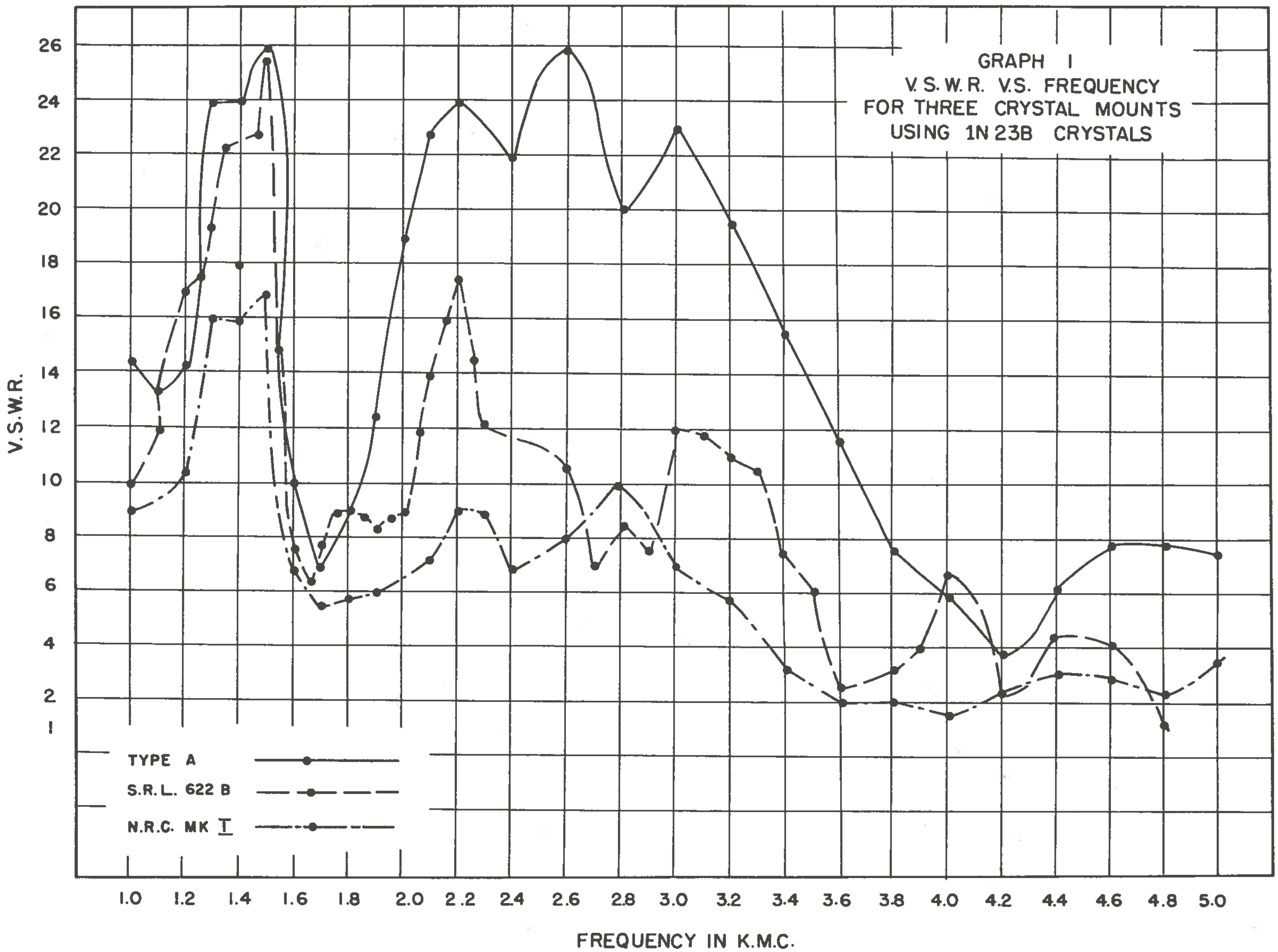
Fig. 5 is an exploded view of the crystal mount with a type-1N23B crystal showing all of the parts described above.

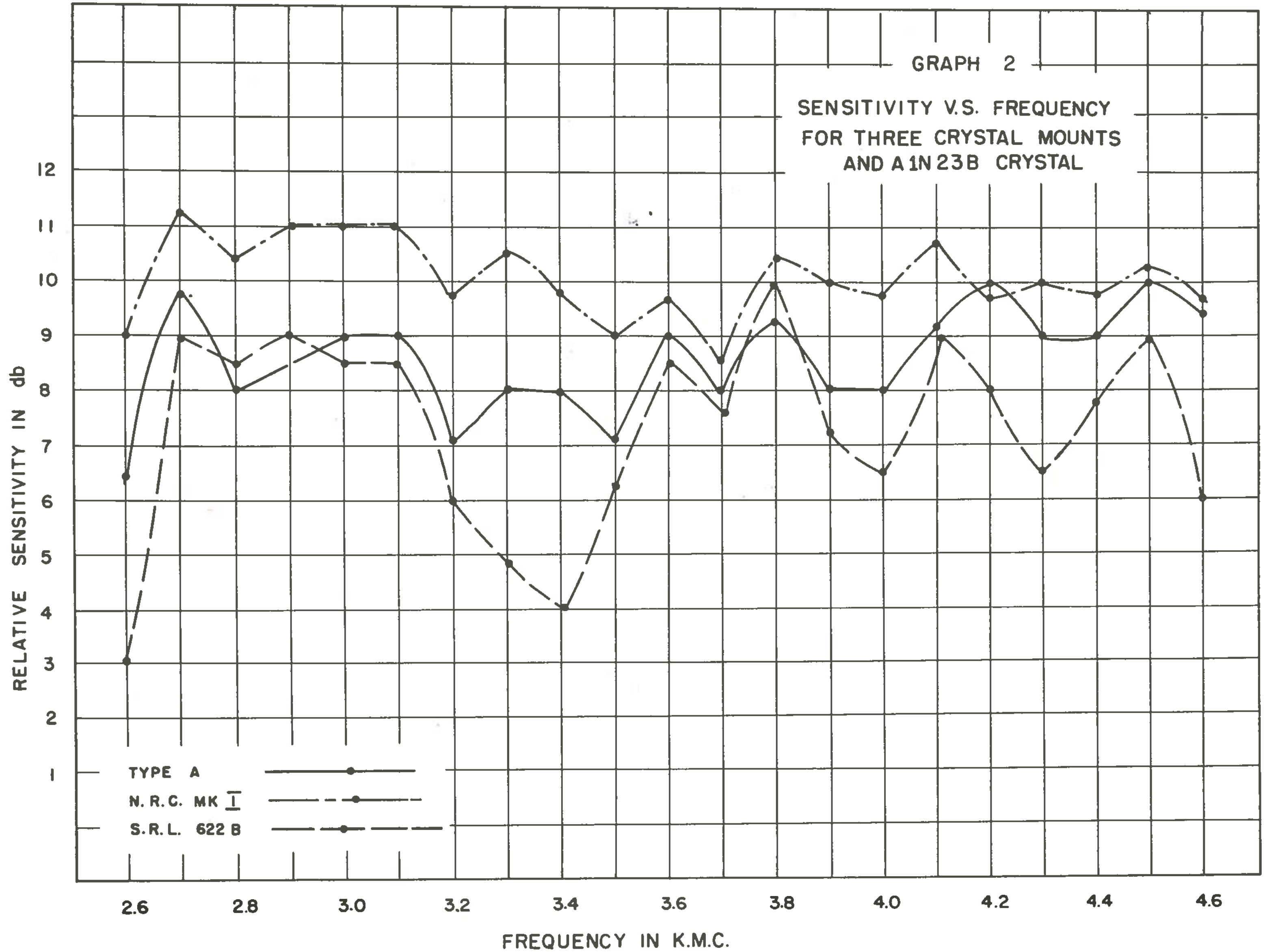
DEVELOPMENT

The initial design of the unit described above was based on a Sinclair Radio Laboratories model-622B crystal mount. This mount was chosen because the performance was typical of coaxial mounts and the mechanical construction lent itself to easy modification. Sensitivity and standing-wave ratio tests were made on this mount with a type-1N23B crystal over the frequency band in question, and the results were compared with those obtained with a type-A mount employing the same crystal. The voltage standing-wave ratio was found to be strongly dependent on carrier level, increasing with an increase in signal. All measurements were made at as low a level as possible, which was approximately -20 dbm, dictated by the sensitivity of the slotted line detector.

The results are shown in Graphs 1 and 2. The model-622B mount was considerably superior to the type-A mount with respect to voltage standing-wave ratio at the low-frequency end of the band, but lower in sensitivity over most of the range. The sensitivity fluctuated rapidly with frequency in both cases owing to the high voltage standing-wave ratio.

In an attempt to improve the sensitivity of the model-622B mount, the video output cap was replaced by one containing a radio-frequency bypass capacitor of approximately 30 $\mu\mu$f. To ensure good contact to the top of the crystal, it was necessary to make the center conductor of the bypass capacitor movable with respect to the outer


GRAPH I
V.S.W.R. V.S. FREQUENCY
FOR THREE CRYSTAL MOUNTS
USING 1N 23B CRYSTALS
V.S.W.R.
26
24
22
20
18
16
14
12
10
8
6
4
2
1
TYPE A
S.R.L. 622 B
N.R.C. MK I
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
4.2
4.4
4.6
4.8
5.0
FREQUENCY IN K.M.C.


GRAPH 2
SENSITIVITY V.S. FREQUENCY
FOR THREE CRYSTAL MOUNTS
AND A 1N 23B CRYSTAL
RELATIVE SENSITIVITY IN db
12
11
10
9
8
7
6
5
4
3
2
1
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
4.2
4.4
4.6
FREQUENCY IN K.M.C.
TYPE A
N. R. C. MK I
S.R.L. 622 B

conductor, and to spring-load it. This resulted in a poor fit for the 0.002-inch teflon dielectric sleeve. The assembly was called the "NRC Mk. I mount". Both voltage standing-wave ratio and sensitivity were improved, as shown in Graphs 1 and 2. The ordinate in Graph 2 does not refer to any absolute level, but only to the relative inputs to the crystal mount when the video output level is maintained constant at a signal-to-noise ratio of about 5 to 1.

The "NRC Mk. II mount" consisted of the Mk. I mount, with the addition of a Telewave type-R063 50-ohm resistor connected across the coaxial line on the generator side of the crystal. Several different methods of mounting the resistor were tried, and the soldering method described above was found most satisfactory in making a good termination over the frequency band desired.

The voltage standing-wave ratio of the Mk. II mount with a type-1N23B crystal is plotted against frequency in Graph 3. This shows very great improvement over the Mk. I mount, except for a section at the high-frequency end of the band. In this range the voltage standing-wave ratio and sensitivity were found to be strongly dependent on the crystal used. This was thought to be due to a resonance at the frequency at which the catwhisker-crystal contact was one-quarter wavelength in the direction of the generator from the apparent location of the radio-frequency short circuit. This difficulty was aggravated by the fact that contact to the crystal was made only at the end rather than along the outside, owing to the necessity of putting the radio-frequency bypass "on from the top". In addition, the bypass cap was somewhat unreliable because of mechanical difficulties involved in its construction.

In an attempt to overcome these difficulties a "Mk. III mount" was constructed with the radio-frequency bypass built into the body. Since the two concentric cylinders comprising the capacitor were a press fit separated by 0.001-inch polyethylene tape, a much higher bypass capacitance (of the order of 200 $\mu\mu$f) was obtained for approximately the same surface area. The Mk. III mount also differed from the Mk. I and the Mk. II mounts in that it used a UG-21D/U connector for the body instead of a UG-21B/U connector which is of smaller inner diameter. It was found by experiment that a ring inserted in the body of the connector to extend the small diameter section up to the top of the slotted center conductor improved the voltage standing-wave ratio at the low end of the band. The location of the ring is shown in Figs. 4 and 5.

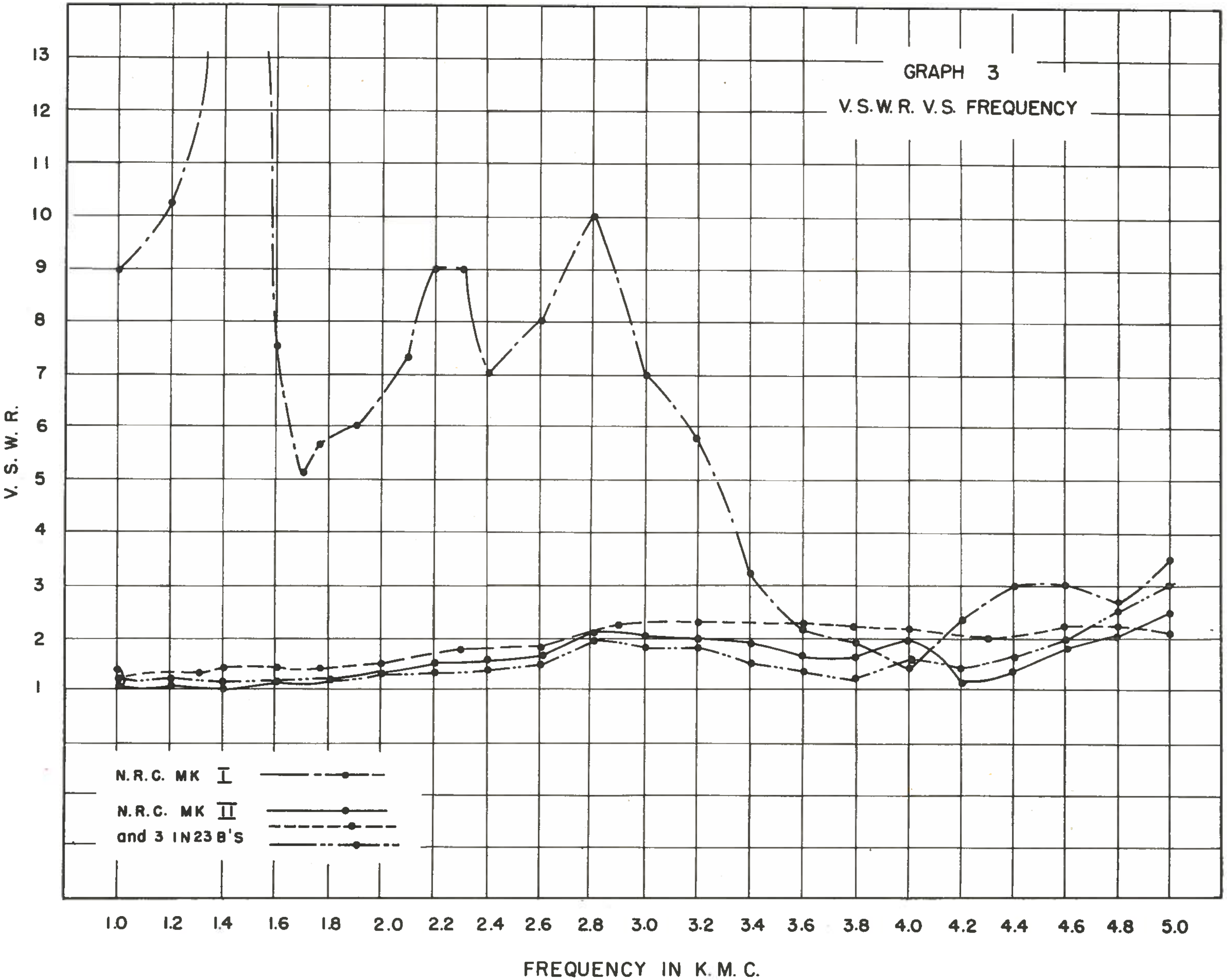
PERFORMANCE

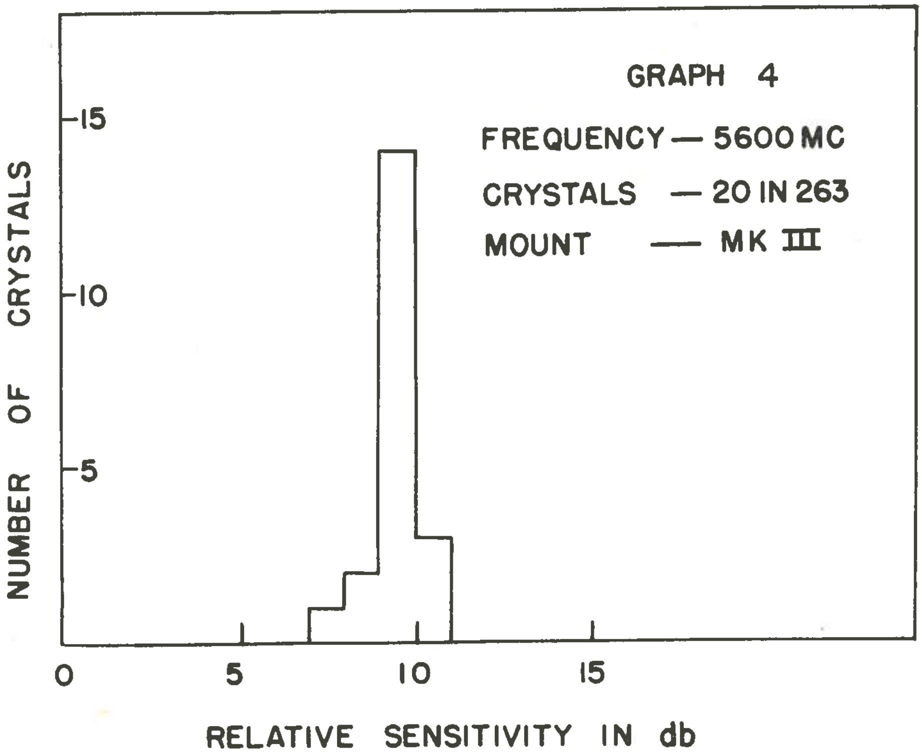
The behaviour of the final broadband coaxial (Mk. III) mount was much the same as that of the Mk. II mount, except in the region around 5000 megacycles. In this region some improvement was obtained, but again the voltage standing-wave ratio was found to depend on the type of crystal used, and varied from one type-1N23B crystal to another. The Philco type-1N263 germanium diode produced good results over the entire frequency range with very little variation from crystal to crystal. A comparison of the uniformity of type-1N263 crystals in the Mk. III crystal mount with that of type-1N23B crystals in a type-A mount can be made from Graphs 4 and 5. Results of measurements of tangential sensitivity for type-A and Mk. III mounts are shown in Graph 6. Voltage standing-wave ratio is plotted in Graph 7 for the same crystals and compared with that obtained with type-1N23B crystals in a Mk. II mount. The lower input impedance of the type-1N263 crystals make them superior in voltage standing-wave ratio over a large portion of the range. The sensitivities of the Mk. III and the type-A mounts are very nearly the same at the high-frequency end of the band because the input impedance of the crystal itself decreases at the higher frequencies, and because resonances in the non-terminated mount are more rapidly damped out by the higher attenuation. At frequencies greater than 6000 megacycles, the presence of the 50-ohm resistor in the Mk. III mount causes a mismatch, and the voltage standing-wave ratio increases rapidly with frequency.

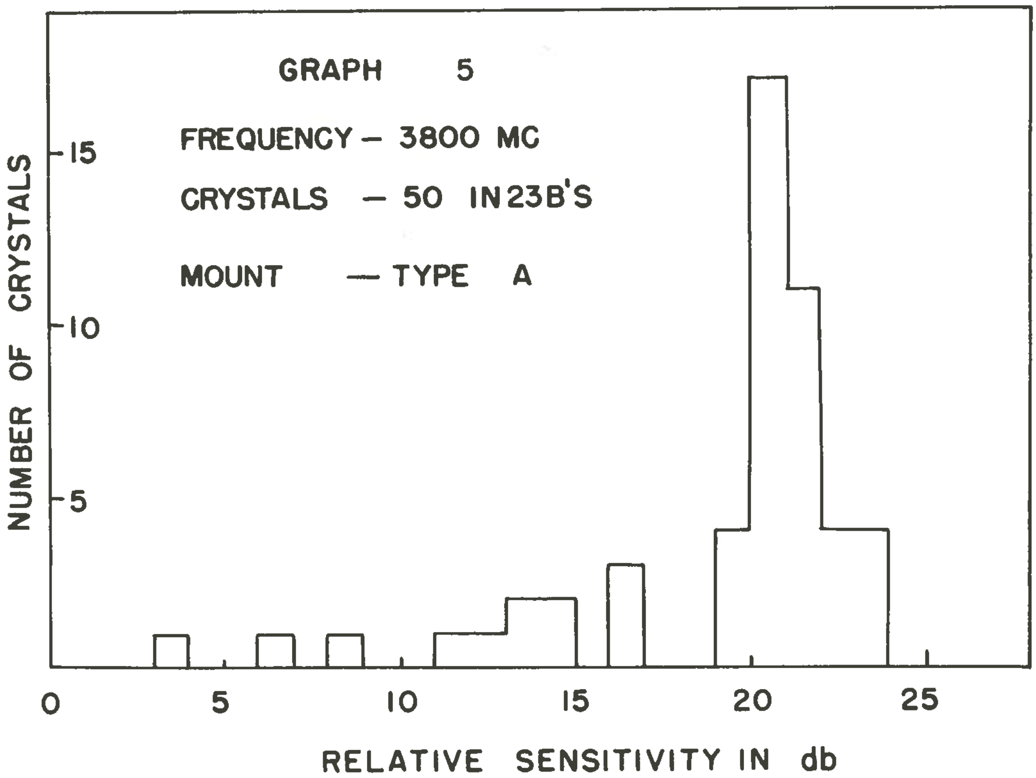
All of the voltage standing-wave ratio and sensitivity measurements were made with a forward bias of 75 μa, d-c. The standing-wave ratio increased rapidly as bias was decreased. The increase in sensitivity due to the bias current varied from 5 db to as much as 15 db, depending on the frequency, type of crystal, and carrier level.

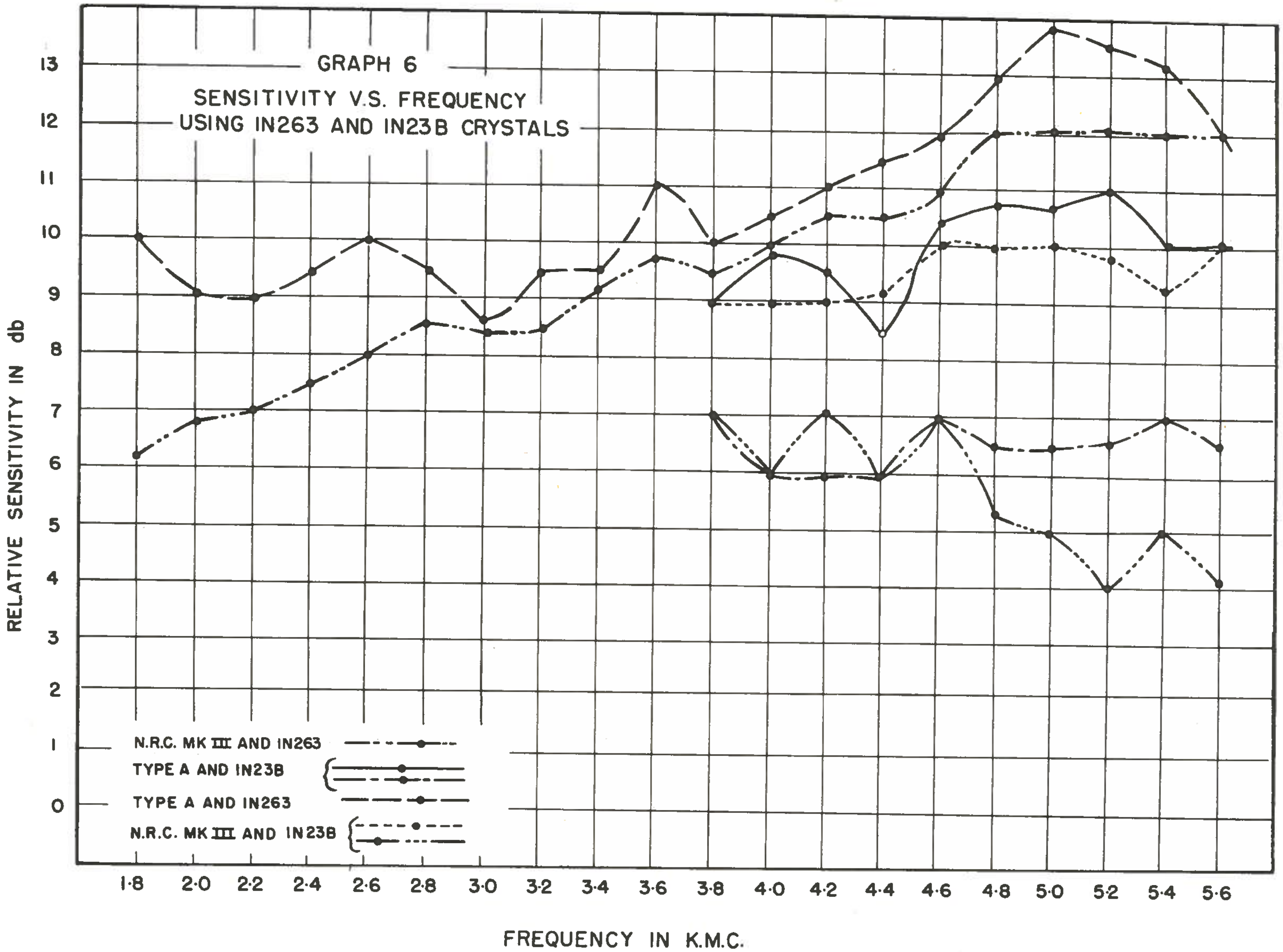
ACKNOWLEDGMENT

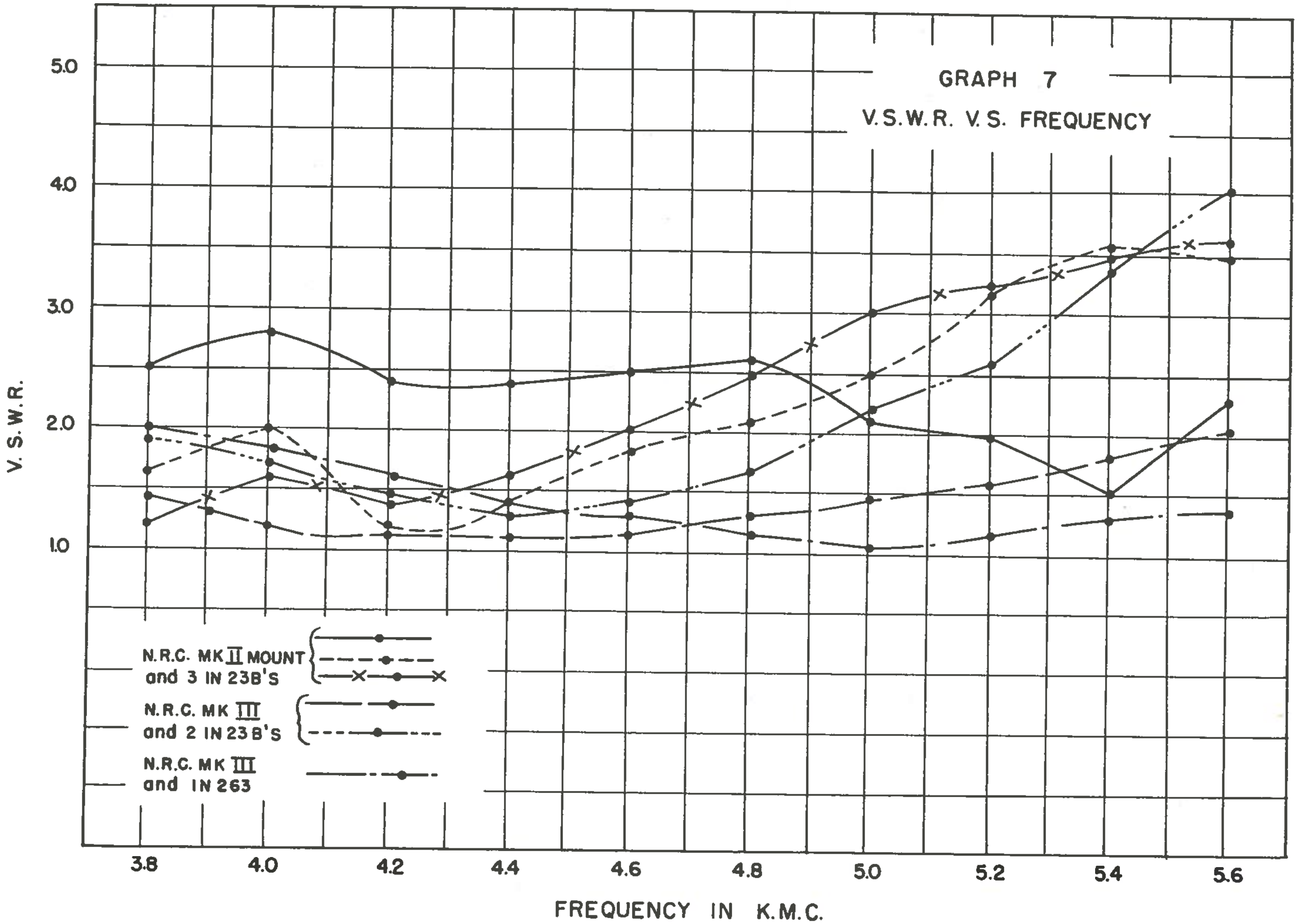
The author is indebted to Mr. A.E. Lindsay for mechanical development of the crystal mount, and to Mr. W.L. Haney, Mr. F.V. Cairns, and Mr. A. Staniforth for many helpful suggestions.

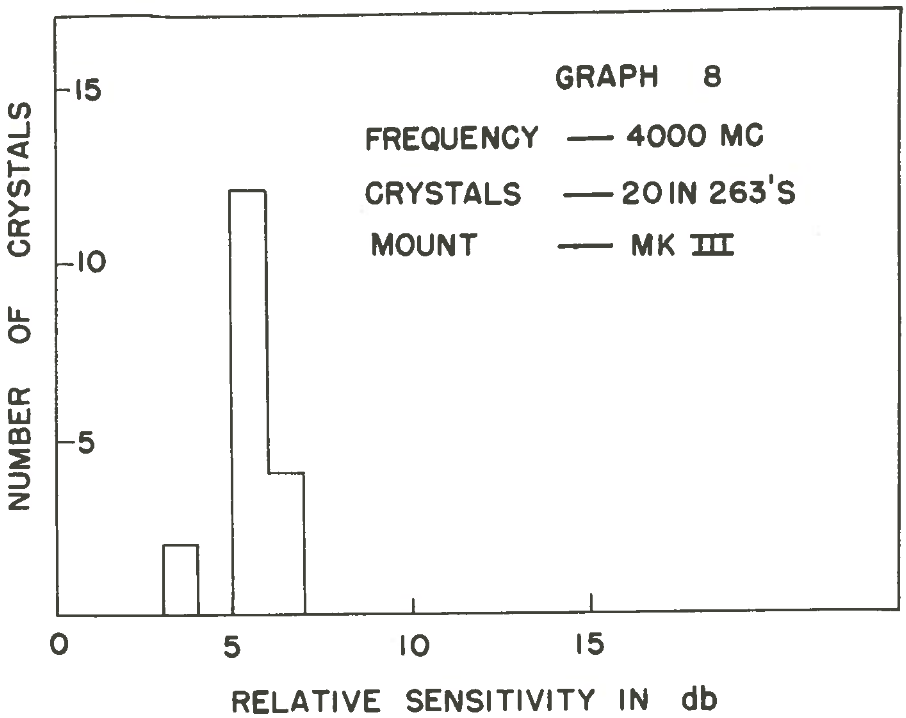

GRAPH 3
V.S.W.R. V.S. FREQUENCY
V. S. W. R.
13
12
11
10
9
8
7
6
5
4
3
2
1
N.R.C. MK I
N.R.C. MK II
and 3 IN23 B'S
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
4.2
4.4
4.6
4.8
5.0
FREQUENCY IN K.M.C.

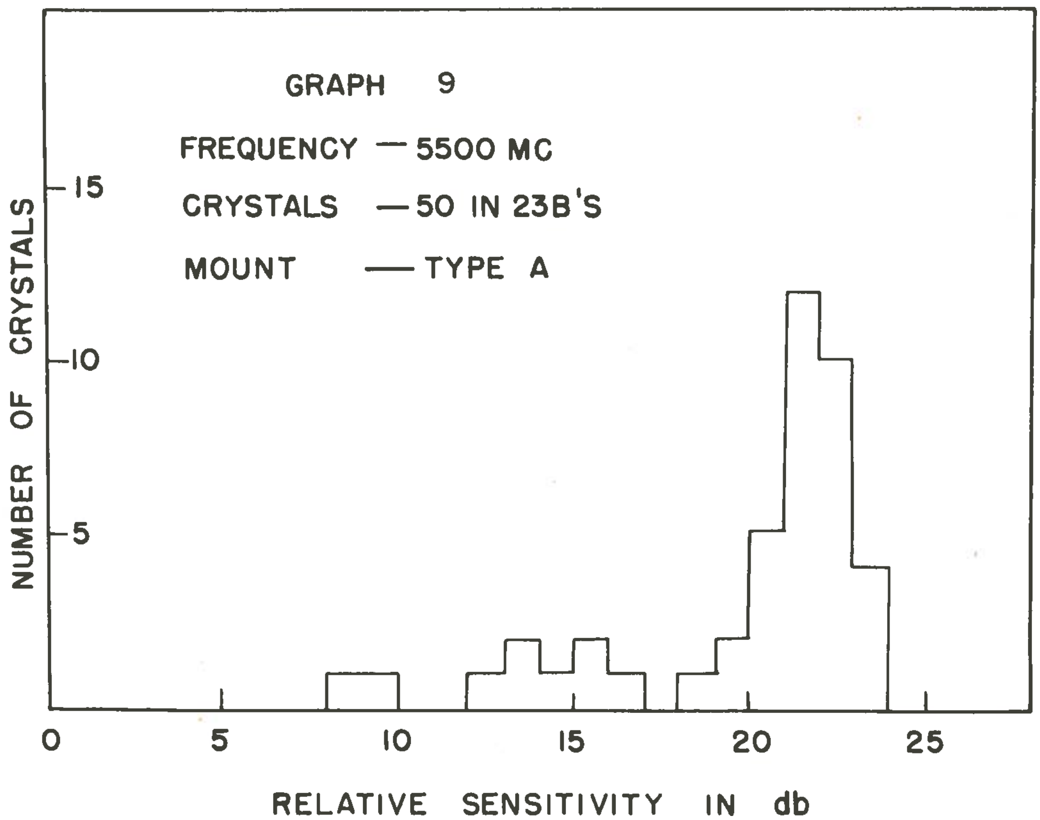

GRAPH 4
FREQUENCY — 5600 MC
CRYSTALS — 20 IN 263
MOUNT — MK III
NUMBER OF CRYSTALS
15
10
5
0
5
10
15
RELATIVE SENSITIVITY IN db


GRAPH 5
FREQUENCY — 3800 MC
CRYSTALS — 50 IN 23B'S
MOUNT — TYPE A
NUMBER OF CRYSTALS
15
10
5
0
5
10
15
20
25
RELATIVE SENSITIVITY IN db


GRAPH 6
SENSITIVITY V.S. FREQUENCY
USING IN263 AND IN23B CRYSTALS
RELATIVE SENSITIVITY IN db
FREQUENCY IN K.M.C.
0
1
2
3
4
5
6
7
8
9
10
11
12
13
1·8
2·0
2·2
2·4
2·6
2·8
3·0
3·2
3·4
3·6
3·8
4·0
4·2
4·4
4·6
4·8
5·0
5·2
5·4
5·6
N.R.C. MK III AND IN263
TYPE A AND IN23B
TYPE A AND IN263
N.R.C. MK III AND IN23B


GRAPH 7
V.S.W.R. V.S. FREQUENCY
5.0
4.0
3.0
2.0
1.0
V.S.W.R.
N.R.C. MK II MOUNT and 3 IN 23B'S
N.R.C. MK III and 2 IN 23B'S
N.R.C. MK III and IN 263
3.8
4.0
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6
FREQUENCY IN K.M.C.


GRAPH 8
FREQUENCY — 4000 MC
CRYSTALS — 20 IN 263'S
MOUNT — MK III
NUMBER OF CRYSTALS
15
10
5
0
5
10
15
RELATIVE SENSITIVITY IN db


GRAPH 9
FREQUENCY — 5500 MC
CRYSTALS — 50 IN 23B'S
MOUNT — TYPE A
NUMBER OF CRYSTALS
15
10
5
0
5
10
15
20
25
RELATIVE SENSITIVITY IN db