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Report on

Loop Circuit "Q" Measurements

and

Defects of Loop Assembly Construction

of the

Models DO, DO-1, DO-2 and DO-3 Radio Direction

Finder Equipments

by

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NAVY DEPARTMENT

BUREAU OF ENGINEERING

Report on

# Loop Circuit "Q" Measurements and Defects of Loop Assembly Construction of the Models DO, DO-1, DO-2 and DO-3 Radio Direction Finder Equipments.

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WASHINGTON, D.C.



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## Appendices

AUTHORIZATION FOR TEST

1. The tests herein reported were authorized by reference (a). Other pertinent data are listed as references (b) to (e) inclusive.

Reference: (a) BuEng. let. S67/69/L5(4-10-W8) of 16 Apr. 1935.
(b) NRL Report No. R-1134.
(c) NRL Report No. R-1141.
(d) Specifications RE 13A 474A.
(e) Specifications RE 69A 175A.

OBJECT OF TEST

2. The object of these tests is to determine first, the extent to which the "Q's" of the CRV-69003 or CRV-69014 loops are influenced by reaction within their associated receiver circuits; second, the "Q's" of these same loops under the conditions as noted in par. (3) below; third, the accuracy of the radio frequency resistance measurements as reported in references (b) and (c), and fourth, the defects in the Models DO, DO-1, DO-2, and DO-3 loop and pedestal assemblies which have developed subsequent to the completion of reference (b).

ABSTRACT OF TEST

3. The tests conducted and reported herein are as follows:

(a) Measurement of the true inductance and distributed capacitance of first, the CRV-69003 loop; second, the CRV-69003 loop with its associated 108" loop-receiver cable, and third, the CRV-69003 loop with the CRV-69005 pedestal assembly and the 108" loop-receiver cable.

(b) Measurement of the radio frequency resistance of first, the CRV-69003 loop; second, the CRV-69003 loop and its associated 108" loop-receiver cable, and third, the CRV-69003 loop with the CRV-69005 pedestal and 108" loop-receiver cable; the loop being tuned with a precision capacitor for each test condition.

(c) Same as (b) except with the loop tuned with a CRV-46031 receiver, without the use of a standard balance antenna and with the balancer coil set at neutral.

(d) Same as (c) except with the balancer coil set at +50.

(e) Same as (c) but with the receiver employing a standard dummy antenna.

(f) Same as (d) but with the receiver employing a standard dummy antenna.

CONCLUSIONS

(a) There is excessive unintentional coupling between the balance and the supposedly inactive sense circuits in the CRV-46031 receiver as a direct result of the leads from these two circuits and which connect to a common anti-capacity switch, being laced together. These circuits are resonant at approximately 800 kcs and react with the external loop circuit when there is maximum coupling between the balancer coil and the loop circuit so as to reduce the loop circuit "Q" at that frequency by a large amount. This reaction is present only when no standard balance antenna is used. The loop circuit "Q's" as reported in references (b) and (c) on the Models DO and DQ equipments respectively, were determined without the use of a standard balance antenna, and without regard to the setting of the balancer control. However, since the loop circuit "Q" curves for the high frequency band for each of the Models DO and DQ equipments show the effect of receiver reaction on the loop circuit "Q's" as evidenced by the dip in the curves, and, since the results of the subject tests show that this reaction is maximum for maximum coupling between the balancer coil and the loop circuit within the receiver, it stands to reason that the balancer coil was set near its +50 position for the tests as reported in references (b) and (c) for the determinations of loop circuit "Q's". Moreover, this reaction is a direct function of the degree of coupling between the balancer coil and the loop circuit within the receiver.

(b) The "Q" of the CRV-69003 loop above, whether tuned with the CRV-46031 or the General Radio precision capacitor is considerably greater than 50 at all frequencies provided, of course, that the CRV-46031 receiver is operated with an antenna. In view of the superiority of the construction of the CRV-69014 loop (Model DQ) over that of the CRV-69003 loop, it is safe to assume that the "Q" of the former loop will be greater than that of the latter at any frequency. The "Q's" of the combined loop circuit used for the subject tests; i.e., loop, pedestal, and 108" loop-receiver cable, is less than 50 for the higher frequencies under all conditions of measurement. The 108" loop-receiver cable offers a greater loss to the loop than does the pedestal by a ratio of approximately two to one.

(c) The tests reported herein revealed that the error in measurement of the radio frequency resistance of the loop circuits of the Model DO equipment as reported in reference (b) and of the Model DQ equipment as reported in reference (c) was as much as 50 to 70% at 1500 kcs and about 15 to 20% at 575 kcs. This is a result of coupling between the loop and the battery leads of the null indicating receiver used in the original test reported in references (b) and (c). At lower frequencies this error can be expected to be proportionally less. These errors were not apparent when the original tests were made for the Models DO and DQ equipments and did not manifest themselves until the separate units of the Model DO loop circuit were measured for radio frequency resistance in the subject tests. The discrepancies in the results of preliminary tests conducted under this problem led to further investigations which brought about the discovery of the lack of sufficient shielding in the null indicating receiver for accurate results.

(d) The method of determining the distributed capacitances of the loop-receiver cables and pedestal as used in the tests reported in reference (b) was found to be inaccurate. The method adopted for the subject tests is believed to give accurate and reliable results.

(e) Certain defects in the construction of the CRV-69005 pedestal assembly and CRV-69003 loop assembly which were not apparent upon completion of reference (b) are as follows:

(1) The wing nuts of the clamping dogs of the CRV-69003 loop assembly do not stay tightened under conditions of severe vibration.

(2) The securing nuts on the large type General Radio plugs on the top of the CRV-69005 pedestal assembly are not mechanically strong enough for this purpose and are subject to corrosion. Both nuts in the case of the CRV-69005 pedestal (ser. No. 42) split in three pieces after a year's service.

(3) The steel ball in the alemite grease fitting in the CRV-69005 pedestal (Ser.No.42) has rusted to the extent that it is useless for the purpose for which it was intended.

(4) The clamping dogs of the CRV-69003 loop (Ser. No.45) do not exactly fit the slots in the CRV-69005 pedestal (Ser.No.42) thus showing the lack of exact interchangeability between units of different serial numbers. This is not in accordance with the requirements of specifications, reference (d).

(5) The plating on the collector rings of the CRV-69005 pedestal has failed to withstand the wiping action of the collector ring brushes after a year's service.

(6) The insulating strip at the top of the CRV-69003 loop (Ser.No.42) warped after about 10 month's exposure to the weather, to the extent that the edges raised off of the loop housing and thus permits moisture to enter freely under this insulating strip.

RECOMMENDATIONS

It is recommended:

(a) That the coupling between the balancer and sense circuits of the CRV-46031 and CRV-46031A receivers be eliminated.

(b) That the Model DQ loop be approved in its present form and that isolantite insulation be used for terminal blocks and lead spacers as employed in the CRV-69014 loop and shaft assembly for all future loop and pedestal assemblies.

(c) That lock washers be provided with the clamping dogs of the CRV-69003 and CRV-69004 loop assemblies to assure that their respective wing nuts will not become loosened under conditions of severe vibration.

(d) That larger securing nuts be provided for the large type

General Radio plugs on the tops of the CRV-69005 and CRV-69005B pedestal assemblies.

(e) That the alemite grease fittings on the CRV-69005 and CRV-69005B pedestals which are exposed to salt atmospheres be provided with watertight caps to protect the steel balls from corrosion.

(f) That more exact interchangeability between units of different serial numbers be provided in accordance with the specification requirements.

(g) That the collector rings be redesigned to have solid silver contact surfaces and that plated contacts not be tolerated on any friction contact member. This applies to both the CRV-69005 and CRV-69005B pedestals.

(h) That the insulating strip at the top of the CRV-69003 loop be of such design as to preclude any tendency to warp.

(i) That the loop adjustable balancing condenser, C16, be sealed at the factory and that its function and method of adjusting be included in the final instruction book.

DESCRIPTION OF MATERIAL UNDER TEST

4. The material under test consisted of one CRV-69003 loop assembly (Ser. No.45), one CRV-69005 pedestal assembly (Ser.No.42), one 108" loop-receiver cable, and one CRV-46031 receiver (Ser.No.42). The loop, pedestal, and loop-receiver cable are of the types employed with the Model DO radio direction finder equipment. Attention is invited to the fact that the CRV-46031 receiver (Ser.No.42) was not used for the radio frequency resistance measurements reported either in reference (b) or (c). For the tests reported in ref. (b), the CRV-69003 loop assembly (Ser.No.45) was used and was tuned with a CRV-46031A receiver (Ser.No.33 - Model DO-3). Also, the CRV-69005B pedestal assembly (Ser.No.33) was used rather than the one employed in the subject tests. A CRV-46031A receiver (Ser.No.45 - Model DO-1) was employed for tuning the CRV-69014 loop assembly (Model DQ) in the tests reported in ref.(c). Neither of the two receivers Serial Nos. 33 or 45 or the CRV-69005B pedestal were available for the tests reported herein, the former receiver and the pedestal having been shipped out of the Laboratory and the latter receiver having been installed in the Laboratory test truck from which it could not be moved owing to the uncertainty of the time when it would be needed for field tests.

METHOD OF TEST

5. The equipment used for making the tests reported herewith is as follows:

General Radio, Standard Signal Generator Type LC-1, Ser. #18
General Radio, Radio Frequency Bridge Type 516C, Ser. #23
General Radio, Precision Capacitor Type 222, Ser. #78
CRV-46031 Receiver, Ser. No.42.
RAA-1 Low Frequency Receiver, Ser. No.8
RAB-1 high frequency receiver, Ser. No.30

6. The standard signal generator and the radio frequency bridge were placed side by side and about 10 inches apart on a bench in and at one side of a screened booth in the Laboratory. The precision capacitor and the CRV-46031 receiver, both used for loop tuning purposes, were placed on the bench at the opposite side of the screened booth. The loop, pedestal, and loop-receiver cable were assembled together and placed in the aisle and midway between the aforementioned benches. The loop was supported on a stand so that its center of rotation was about 30 inches above the floor, and its plane at right angle to the floor. The RAA-1 and RAB-1 receivers, used for indicating bridge balance within their respective frequency ranges were set outside of the screened booth and several feet across the room away from the booth.

7. Radio frequency signals from the standard signal generator were applied to the radio frequency bridge input through the standard output cord accompanying the standard signal generator. A connection from the loop center (ground to one side of the loop) was made to the "series resistance" terminals of the radio frequency bridge through a shielded low capacity cable approximately two feet in length, with the shield at ground potential. This connection places the loop in series with the decade resistance arm of the bridge. One end of the connecting cable was provided

with the male end of an ordinary receptacle so that it could be plugged into the female end of a receptacle connected to the lead from the loop center or to a similar receptacle which was shorted, this latter receptacle being required for obtaining the initial bridge balance for each frequency at which measurements were made. The "unknown" terminals of the radio frequency bridge were connected to a 50 ohm resistor and an 0.001 microfarad condenser in series. The "detector" terminal of the radio frequency bridge was connected to the antenna and ground terminals of an RAA-1 or RAB-1 receiver (depending upon the frequency) with a triple shielded conductor, the shield of which served as the low potential return. The output terminals of the loop, or loop and loop-receiver cable, or loop, pedestal, and loop cable, whichever unit or combination of units was concerned with a particular test, was then connected to the CRV-46031 receiver or precision condenser as required for tuning purposes.

8. The test set up as described in the foregoing affords a means for determining the radio frequency resistance of the unloaded or loaded loop circuit by the substitution method and a means for determining the true inductance and distributed capacitance of the loop circuit. In these tests, the loop terminals are at equal potential above ground, while the loop housing, pedestal frame and cable shield are at ground potential. The common ground connection was made from the standard signal generator case to the shielded booth.

9. The test procedures as described below apply to the loop, loop pedestal, and loop receiver cable normally assembled together. Repeat runs were made for the loop and cable direct connected together and then for the loop alone.

(a) Unloaded Loop Circuit. In this test, the loop circuit was tuned with the General Radio Type 222 precision condenser. The following steps were followed in making the tests.

(1) The RAA-1 or RAB-1 receiver, depending upon the frequency, was tuned to the frequency to which the standard signal generator was adjusted.

(2) The cable to the loop center from the radio frequency bridge was disconnected from the loop and shorted at the loop end.

(3) The radio frequency bridge was adjusted for balance by adjusting the decade resistance arm to balance the fixed resistance in the "unknown" arm; and adjusting the power factor and capacitance controls to balance the inserted capacitance in the "unknown" arm and the capacitance of the cable to the loop center. The setting of the decade resistance was then noted.

(4) The "short" was removed from the loop bridge cable and the cable connected to the loop center. Attention is called to the fact that by shorting the loop-bridge cable at the loop end, its constants are included in the initial adjustment of the radio frequency bridge and hence do not enter into the measurement of the

radio frequency resistance or distributed capacitance of the loop circuit under test.

(5) The loop circuit was tuned to resonance and the decade resistance was reduced by an amount equal to the loop circuit resistance as determined by a new indication of null or balance. The setting of the decade resistor when subtracted from its initial setting is the radio frequency resistance of the loop circuit at the test frequency. The setting of the precision condenser was noted.

(6) This procedure was repeated for several frequencies as indicated on Plate 2. The setting of the precision condenser when plotted against their corresponding frequencies converted in terms of wave length squared produced the curves shown in Plate 1, from which the true inductance and distributed capacitance of the loop circuit under test may be determined.

(b) Loaded Loop Circuit. For this test the loop circuit was connected to the CRV-46031 receiver, which provided a normal load on the loop circuit under test and afforded a means for tuning the loop. The procedure for measuring the radio frequency resistance of the loop circuit when loaded was the same as described above except, as follows:

(1) The loop circuit was tuned with the CRV-46031 receiver.

(2) Measurements of the radio frequency resistance of the loop circuit, under test, were made with the balancer coil of the CRV-46031 receiver set at +50 and with and without a standard dummy antenna connected to the receiver.

(3) Measurements of the radio frequency resistance of the loop circuit, under test, were made under similar conditions as (2) except that the balancer coil was set at its neutral position.

DATA RECORDED DURING TESTS

10. Complete data were recorded on all tests and this information is contained in Plates 1 to 11 appended hereto.

PROBABLE ERRORS IN RESULTS

11. It is believed that the test procedures described in the foregoing offer the most precise as well as practical means for determining the radio frequency resistance, true inductance and distributed capacitance of a loop circuit, yet devised with the equipment available for these types of tests. The tests reported herein have proved that the results reported in references (b) and (c) for similar measurements were subject to errors which did not manifest themselves at the time those tests were made, owing to the fact that these tests were made on the entire loop circuit (loop, pedestal, and loop-receiver cable) of the particular equipment concerned;

namely, the Models DO and DQ equipments. Had measurements of radio frequency resistance been made on the loops alone and then on the loops with their corresponding cables, as was done for the subject tests, these errors would have been self evident.

12. An attempt was made to measure the radio frequency resistance of the CRV-69003 loop serial no. 45 with and without the CRV-69005 pedestal serial no.42 and the 108" loop-receiver cable, with the loop circuit under test tuned with either the CRV-46031 receiver, serial no.42, or a General Radio Type 222 precision condenser and using the same measuring equipment as used for the tests described in references (b) and (c) and with the test set up made in the penthouse of the Laboratory. It is to be noted especially that the receiver used for indicating bridge balance was an experimental battery operated receiver and the same as used for the tests reported in references (b) and (c).

13. Measurements of radio frequency resistance made under these conditions gave results for the loop, pedestal, and loop-receiver cable combinations when tuned with the CRV-46031 receiver which agreed very closely with those obtained in reference (b). However, the results obtained showed that while the radio frequency resistance of the loop and loop-receiver cable combination was, for any given frequency, higher than for the loop alone, they were also higher than for the loop, pedestal, and loop cable combination. Similar results were obtained when the loop circuits under test were tuned with the General Radio precision condenser. The results obtained when the loop circuits were tuned with the precision condenser were less than the corresponding values obtained when the loop circuits were tuned with the CRV-46031 receiver by amounts which were reasonable enough to account for the radio frequency resistance of the loading circuits within the CRV-46031 receiver. Obviously then, the inconsistency which exists between the results obtained for the loop and loop-receiver cable combination and the corresponding results obtained for the loop, pedestal, and loop-receiver cable combination is not a function of reaction on the part of the CRV-46031 receiver but is a function of the errors inherent with the measuring system.

14. An investigation revealed that there was sufficient field from the loop to couple with the experimental receiver through its battery leads to the extent that a signal could be heard in the headphones with the receiver disconnected from the bridge. Moving this receiver further away from the radio frequency bridge lessened this coupling somewhat, but under no condition within practical limits could it be entirely eliminated. This coupling introduced phase difficulties which give false indications of bridge balance and hence erroneous readings. The amount of coupling was a function of the "Q" of the loop circuit under test. It was found that the only solution to this problem was to isolate the measuring equipment and the units under test from the receiver used for indicating null by placing the former in a screened booth and locating the latter at some remote distance from the screened booth as was done for the tests reported herein. Furthermore, it is of vital importance that the receiver or receivers used for null indicating purposes be very well shielded.

15. In the tests reported in reference (b) for radio frequency resistance, the measuring equipment and loop circuit under test were

located in a screened booth, while the experimental battery operated receiver used for null indicating purposes was located outside of the screened booth but only about five feet away from the end of the loop. For the radio frequency resistance measurements reported in ref.(c) the arrangement of the equipment was similarly arranged except that the experimental receiver located outside of the screened booth was only about 3 feet from the end of the loop. In both instances, the experimental receiver was directly exposed to the field of the loops. Therefore, the results of the measurements for radio frequency resistance, reported in refs. (b) and (c) for the Models DO and DQ loop circuits respectively, are subject to the same errors as was noted in the similar tests made in the penthouse. Moreover, since the coupling between the DQ loop and the null indicating receiver was greater than for the DO loop, the errors of measurement are greater for the former than for the latter.

16. In the subject tests for radio frequency resistances as well as for corresponding tests reported in references (b) and (c), the results are independent of the accuracy of the radio frequency bridge since these results were obtained by the substitution method, but they are dependent upon the degree of coupling between the loop and the null indicating receiver. The frequency at which any particular measurement was made is dependent upon the accuracy to which the standard signal generator could be set which is within ±0.1%. The following table gives the estimated accuracies with which radio frequency resistances were measured for the tests reported herein, and the probable inaccuracies of similar measurements reported in references (b) and (c).

| Description of Loop Circuit | Accuracy of Measurement |
|---|---|
| (1) CRV-69003 Loop (Ser.No.45) CRV-69005 Pedestal and 108" Cable (subject tests) | ±1% in freq.<br>±0.2 ohm in res. |
| (2) Model DO loop (original tests reported in ref. (b) | ±1% in freq.<br>15% low in res. at 575 kcs, 50% low in res. at 1500 kcs |
| (3) Model DQ loop (original tests reported in ref.(c) | ±1% in freq.<br>20% low in res. at 575 kcs., 70% low in res. at 1500 kcs. |

Note that for (2) and (3) the percent of inaccuracy in the r.f. resistance measurements decreases with frequency.

17. The accuracy of the calculations for loop circuit "Q" at any frequency from the corresponding resistance measurement at the same frequency for the subject tests is within the limits of ± 1%. The loop circuit "Q's" as reported in references (b) and (c) are high in value from 575 to 1500 kcs since their corresponding i.f. resistance values are low.

18. The calculations of the true inductances and distributed capacitances of the CRV-69003 loop, CRV-69005B pedestal leads and 108" loop receiver cable leads, taken separately or collectively, and determined

from the wave length squared curves shown on Plate 1 of this report are accurate to within ±5% for inductance and ±10% for capacitance. A further discussion of this subject as applying to the similar results reported in references (b) and (c) will be given under RESULTS OF TEST.

RESULTS OF TEST

19. True Inductance and Distributed Capacitance. Plate 1 shows wave length squared curves for determining the true inductances and distributed capacitances of the CRV-69003 loop with and without its associated CRV-69005 pedestal assembly and 108" loop-receiver cable. The true loop circuit inductances as calculated from data taken from the three curves shown on Plate 1 are as follows:

| | |
|---|---|
| CRV-69003 loop alone. . . . . . . . . . . . . . . . . | 59.2 microhenries |
| CRV-69003 loop with 108" cable... . . . . . . . . . | 60.2 " |
| CRV-69003 loop with CRV-69005 pedestal and 108" cable. . . . . . . . . . . . . . . . . . . . | 61.7 " |

The calculated inductance values are based on the formula

$$L = \frac{\frac{\Delta \lambda^2}{\Delta C}}{3.553}$$

Where $\frac{\Delta \lambda^2}{\Delta C}$ = incremental slope of the wavelength squared curve

$L$ = true loop circuit inductance - microhenries

$3.553$ = a constant

From the above data, then, the inductances of the 108" cable and CRV-69005 pedestal assembly are obviously 1.0 and 1.5 microhenries, respectively.

20. The total inductance of the loop, pedestal, and receiver coupling cable down to the receiver connecting terminals as measured under the subject test is 2.37% lower in value than that given in par. (c) page 57 of NRL Report No. R-1134 for the Model DO equipment. It is considered to be, however, in close agreement with the original value in view of the fact that it was measured by a different procedure. Par. 20 of NRL Report No. R-1141 gives a value of 64.3 microhenries for the true inductance of the CRV-69014 loop and its associated pedestal and loop receiver cable.

21. The curves on Plate 1 show the distributed capacitance of the CRV-69003 loop to be 16 micromicrofarads, that of the pedestal leads to be 32 micromicrofarads and that of the loop-receiver cable to be 72 micromicrofarads. Par. (d) on page 57 of ref. (b) states that the distributed capacitance is 12 micromicrofarads for the CRV-69003 loop, 33.9 micromicrofarads for the CRV-69005B pedestal leads and 103 micromicrofarads for the loop receiver cable. The distributed capacitance of the loop was determined by taking the difference between the total distributed capacitance of the loop pedestal and cable, and the sum of the measured distributed capacitances of the pedestal leads and the loop receiver cable. These

figures as given in ref. (b) for the loop receiver cable and pedestal leads were applied to ref. (c) and appear in par. 20 of that reference. It will be noted that these figures do not agree with the corresponding figures derived from Plate 1 appended hereto. It will be noted also that the total distributed capacitance of the Model DO loop, pedestal, and cable combination and shown on Plate 4 of ref.(b) is 150 micromicrofarads which is greater than that shown on Plate 1 of this report by 30 micromicrofarads. The following discussion will explain the reasons for this discrepancy and will apply to ref.(c) as well as (b) for it will be noted that on Plate 4 of ref. (c) the total distributed capacitance of the Model DQ loop and its pedestal and loop-receiver cable is 130 micromicrofarads.

22. The procedure described for determining the wave length squared curves for the subject equipment permits very precise tuning of the loop. Hence the results shown on Plate 1 of this report are more nearly correct than for those shown on Plate 1 of refs. (b) or (c). In these latter instances the loop was tuned with a precision condenser at the receiver end of the loop receiver cable. The test radio frequency signal was fed from a standard signal generator directly into the loop center and resonance was indicated by a "slide back" type of vacuum tube voltmeter bridging the precision condenser. Now while this method is satisfactory it is less precise than the bridge method owing to the fact that one cannot detect the absolute point of resonance by this visual means as by the oral means afforded by the bridge method. It is reasonable to assume that the error in determining the point of resonance by the visual method would be constant for all frequencies, but this error, probably as much as ± 5% in terms of tuning capacity, would be sufficient to change the slope of the wave length square curve by such an amount as to indicate a higher distributed capacitance for the loop circuit than actually exists. Since the distributed capacitances of Models DO loop as reported in ref. (b) and that of Model DQ loop as reported in ref. (c) were measured under the same precedure, it is reasonable to assume that the same difference between their distributed capacitances would continue to exist if they were both obtained by the bridge method. Hence, by this reasoning if the distributed capacitance of the total loop circuit as determined in the subject tests for the Model DO loop is 120 micromicrofarads, that of the Model DQ loop would be 100 micromicrofarads.

23. The above explanation for the discrepancies may well be applied to the discrepancies found in the calculations for true loop circuit inductance.

24. The distributed capacitances of the CRV-69005B pedestal and 108" cable used for the tests in ref.(b) were measured on a General Radio Type 650A impedance bridge. In making these measurements the two leads were not at equal potential with respect to ground and therefore do not simulate actual operating conditions and as a result the capacity measurements must be somewhat in error. It will be noted that the measurement of the distributed capacitance of the CRV-69005B pedestal lead as determined by the method described in ref.(b) is 33.9 micromicrofarads, whereas for the distributed capacitance of the CRV-69005 pedestal leads as determined from the wave length squared curves shown on Plate 1 of this report is 32 micromicrofarads. In this latter instance, both of the leads in the pedestal are at equal potential above ground and the pedestal housing is at

ground potential. The capacitance thus determined is the normal value. Similarly, the impedance bridge method gives a value of 103 micromicrofarads for the distributed capacitances of the loop-receiver cable, whereas the wave length squared curves shown on Plate 1 gives a value of only 72 micromicrofarads showing the effect of the stray capacitances between the cable leads and shields in the latter method and not accounted for in the former method.

25. For convenience the following table is given to show to what extent the results given in ref. (b) and (c) for the distributed capacitances of the Models DO and DQ loop circuits are affected by the results obtained from the subject tests.

| Description | Model DO, ref. (b) | | Model DQ, ref. (c) | |
|---|---|---|---|---|
| | Orig. Value | New Value | Orig. Value | New Value |
| Total loop circuit; i.e. loop, pedestal, and 108" cable. | 150 | 120 | 130 | 100 |
| Pedestal leads | 33.9 | 32.0 | - | - |
| Cable leads | 103.0 | 72.0 | 103.0 | 72.0 |
| Loop | 12.6 | 16.0 | - | - |
| Loop and pedestal leads | 46.5 | 48.0 | 27.0 | 28.0 |

Note: All values in micromicrofarads.

26. Plate 2 shows radio frequency resistance curves for the CRV-69003 loop with and without its associated CRV-69005 pedestal and 108" loop-receiver cable and with the loop circuits tuned with a General Radio precision capacitor. It will be observed that these curves are without irregularities and that the 108" cable offers more loss to overall loop circuit than does the pedestal. Corresponding loop circuit "Q's" shown on Plate 3 were calculated from the formula

$$Q = \frac{\omega L}{R}$$

where L = loop circuit inductance in millihenries

R = loop circuit radio frequency resistance in ohms

$\omega = 2\pi f$, where f = frequency in kilocycles.

The "Q's" were calculated for corresponding radio frequency resistances and from the loop circuit inductance determined for the given circuit condition from the wave length squared curves shown on Plate 1. The "Q's" of the loop alone and unloaded, are better than 79 whereas they fall below the specification limit of 50 (par. 79, ref. (e)) above 1200 kcs when the loop is used with the 108" loop-receiver cable and above 900 kcs when it is used with the pedestal and 108" loop-receiver cable. In view of these results plus the fact that the construction of the Model DQ loop (CRV-69014) is superior to that of the CRV-69003 loop, it is safe to assume that the Q of the CRV-69014 loop alone will be better than 80 at all frequencies.

27. Plate 4 shows radio frequency resistance curves of the

CRV-69003 loop with and without its associated CRV-69005 pedestal and 108" loop-receiver cable, tuned with the CRV-46031 receiver and with the balancer coil of the receiver set at its neutral position. No standard dummy antenna was used with these measurements. Corresponding calculated loop circuit "Q" curves are shown on Plate 5. Radio frequency resistance curves obtained under similar conditions but with the balancer coil of the receiver at +50 are shown on Plate 6; while corresponding calculated loop circuit "Q" curves are shown on Plate 7. The loop circuit "Q" curves shown on Plates 5 and 7 were calculated from the formula of par. 26, for corresponding radio frequency resistances shown on Plates 4 and 6 respectively, and suitable inductance values obtained from the wave length squared curves shown on Plate 1 of this report. To each of the inductance values obtained from these curves is added 12 microhenries, the inductance present in distributed form in the receiver loop circuit. It will be noted on Plate 4 that there is a slight irregularity at approximately 750 kcs in the radio frequency resistance curve for the loop, pedestal, and loop-receiver cable combination, whereas on Plate 6 all curves show a decided peak at approximately 800 kcs when the balancer coil is set at +50 instead of neutral. This irregularity in the upper curve on Plate 4 and the peaks in all of the curves on Plate 6 are due to interaction between the balancer circuit and the supposedly inactive sense circuit as a result of coupling between the leads of the two circuits which are laced together and connected to a common anti-capacity switch operated by the band switch controlled from the front panel of the CRV-46031 receiver.

28. The use of a standard dummy antenna changes the constants of the balancer circuit to the extent that interaction between it and the sense circuit is eliminated. This is illustrated on Plates 8 and 10. As is to be expected, the radio frequency resistances of loop circuits when loaded and tuned with the CRV-46031 receiver are higher than when the same circuits are tuned with the General Radio precision condenser. Hence the corresponding loop circuit "Q's" are less for the loaded loop circuits than for the unloaded loop circuits.

29. The loop circuit "Q" curves shown in Plates 9 and 11 and for the test conditions where the standard dummy antenna is employed with the CRV-46031 receiver, show that the loop circuit "Q" value is less than 50 at frequencies greater than 930 kcs. It is to be noted also that were the corresponding curve on Plate 9, ref.(b), corrected to account for the errors in measurement as discussed under pars. 14 to 16 of this report, that this curve would agree very closely with that shown on Plates 9 or 11.

30. A summary of the defects noted as a result of the subject tests and those defects noted in the construction of the loop and pedestal assemblies for the Models DO, DO-1, DO-2, and DO-3 equipments which were not apparent upon the completion of ref. (b) are as follows:

(a) **Excessive** coupling exists between the balancer and sense circuits of the CRV-46031 and CRV-46031A receivers when no antenna is used such that its reaction on the external loop circuit is to reduce the loop circuit "Q" very appreciably at approximately 800 kcs when there is maximum coupling between the balancer coil and the loop circuits within either receiver.

(b) The wing nuts on the clamping dogs on the CRV-69003 or CRV-69004 pedestal assemblies do not remain tight under conditions of severe vibrations.

(c) The securing nuts on the large type General Radio plugs in the tops of the CRV-69005 or CRV-69005B pedestal assemblies are not mechanically strong for their intended purpose and are subject to corrosion. In the case of the CRV-69005 pedestal assembly (Ser. No.42) both nuts split in 3 pieces and showed convincing evidence of corrosion. This failure of the securing nuts took place after about a year's service.

(d) The steel ball in the alemite grease fittings in the CRV-69005 or CRV-69005B pedestal assemblies, and those which are exposed to the weather have rusted to such extent that they are useless for the purpose for which they were intended.

(e) The CRV-69003 loop assembly, Ser.No.45, does not exactly fit the CRV-69005 pedestal assembly (Ser.No.42). This is a decided indication that interchangeability between units having different serial numbers does not exist for all units as required by the specifications of ref. (d).

(f) The plating on the collector rings of the CRV-69005 pedestal assembly (Ser.No.42) is entirely too thin and wore through to a brass contact after a year's service.

(g) The insulating strip at the top of the CRV-69003 loop (Ser.No.42) warped after about 10 months' exposure to the weather, and to the extent that the edges curled away from the loop housing thus permitting water to enter under the insulating strip.

CONCLUSIONS

31. There is excessive unintentional coupling between the balance and the supposedly inactive sense circuits in the CRV-46031 receiver as a direct result of the leads from these two circuits and which connect to a common anti-capacity switch, being laced together. These circuits are resonant at approximately 800 kcs and react with the external loop circuit when there is maximum coupling between the balancer coil and the loop circuit so as to reduce the loop circuit "Q" at that frequency by a large amount. This reaction is present only when no standard balance antenna is used. The loop circuit "Q's" as reported in refs. (b) and (c) on the Models DO and DQ equipments respectively, were determined without the use of a standard balance antenna, and without regard to the setting of the balancer control. However, since the loop circuit "Q" curves for the high frequency band for each of the Models DO and DQ equipments show the effect of receiver reaction on the loop circuit "Q's" as evidenced by the dip in the curves, and, since the results of the subject tests show that this reaction is maximum for maximum coupling between the balancer coil and the loop circuit within the receiver, it stands to reason that the balancer coil was set near its +50 position for the tests as reported in refs. (b)

and (c) for the determinations of loop circuit "Q's". Moreover, this reaction is a direct function of the degree of coupling between the balancer coil and the loop circuit within the receiver.

32. The "Q" of the CRV-69003 loop alone, whether tuned with the CRV-46031 or the General Radio precision capacitor is considerably greater than 50 at all frequencies provided, of course, that the CRV-46031 receiver is operated with an antenna. In view of the superiority of the construction of the CRV-69014 loop (Model DQ) over that of the CRV-69003 loop, it is safe to assume that the "Q" of the former loop will be greater than that of the latter at any frequency. The "Q's" of the combined loop circuit used for the subject tests; i.e., loop, pedestal, and 108" loop-receiver cable, is less than 50 for the higher frequencies under all conditions of measurement. The 108" loop-receiver cable offers a greater loss to the loop than does the pedestal by a ratio of approximately two to one.

33. The tests reported herein revealed that the error in measurement of the radio frequency resistance of the loop circuits of the Model DO equipment as reported in ref. (b) and of the Model DQ equipment as reported in ref. (c) was as much as 50 to 70% at 1500 kcs and about 15 to 20% at 575 kcs. This is a result of coupling between the loop and the battery leads of the null indicating receiver used in the original test reported in refs. (b) and (c). At lower frequencies this error can be expected to be proportionally less. These errors were not apparent when the original tests were made for the Models DO and DQ equipments and did not manifest themselves until the separate units of the Model DO loop circuit were measured for radio frequency resistance in the subject tests. The discrepancies in the results of preliminary tests conducted under this problem led to further investigations which brought about the discovery of the lack of sufficient shielding in the null indicating receiver for accurate results.

34. The method of determining the distributed capacitances of the loop-receiver cables and pedestal as used in the tests reported in ref. (b) was found to be inaccurate. The method adopted for the subject tests is believed to give accurate and reliable results.

35. Certain defects in the construction of the CRV-69005 pedestal assembly and CRV-69003 loop assembly which were not apparent upon the completion of ref. (b) are as follows:

(1) The wing nuts of the clamping dogs of the CRV-69003 loop assembly do not stay tightened under conditions of severe vibration.

(2) The securing nuts on the large type General Radio plugs on the top of the CRV-69005 pedestal assembly are not mechanically strong enough for this purpose and are subject to corrosion. Both nuts in the case of the CRV-69005 pedestal (Ser.No.42) split in three pieces after a year's service.

(3) The steel ball in the alemite grease fitting in the CRV-69005 pedestal (Ser.No.42) has rusted to the extent that it is useless for the purpose for which

it was intended.

(4) The **clamping** dogs of the CRV-69003 loop (Ser.No.45) do not exactly fit the slots in the CRV-69005 pedestal (Ser.No.42) thus showing the lack of exact interchangeability between units of different serial numbers. This is not in accordance with the requirements of specifications, ref.(d).

(5) The plating on the collector rings of the CRV-69005 pedestal has failed to withstand the wiping action of the collector ring brushes after a year's service.

(6) The insulating strip at the top of the CRV-69003 loop (Ser.No.42) warped after about 10 months' exposure to the weather, to the extent that the edges raised off of the loop housing and thus permits moisture to enter freely under this insulating strip.

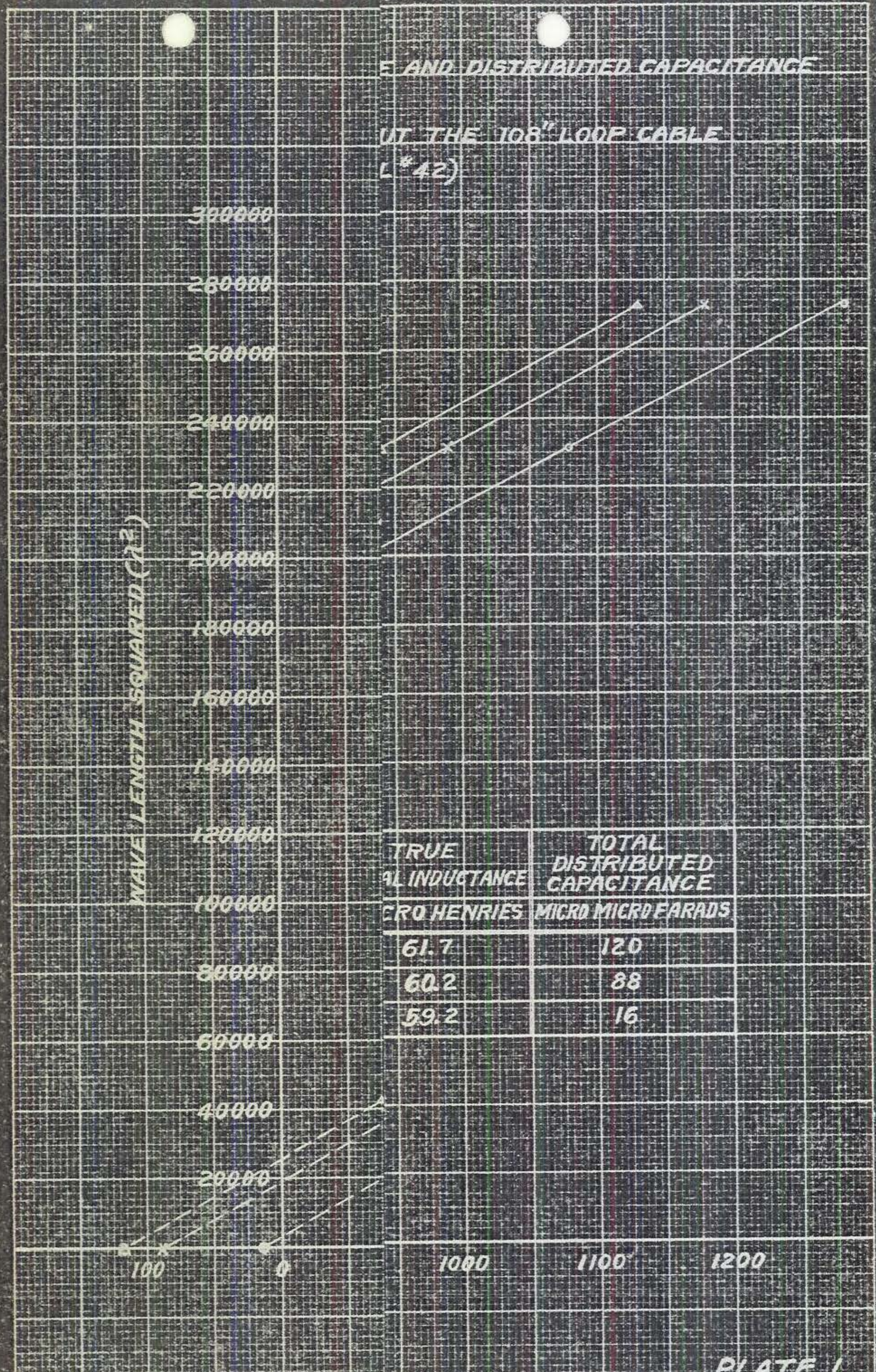
E AND DISTRIBUTED CAPACITANCE
UT THE 108" LOOP CABLE
L #42)
WAVE LENGTH SQUARED (λ²)
300000
280000
260000
240000
220000
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
TRUE
AL INDUCTANCE
ERO HENRIES
TOTAL
DISTRIBUTED
CAPACITANCE
MICRO MICRO FARADS
61.7
120
60.2
88
59.2
16
100
0
1000
1100
1200

PLATE I

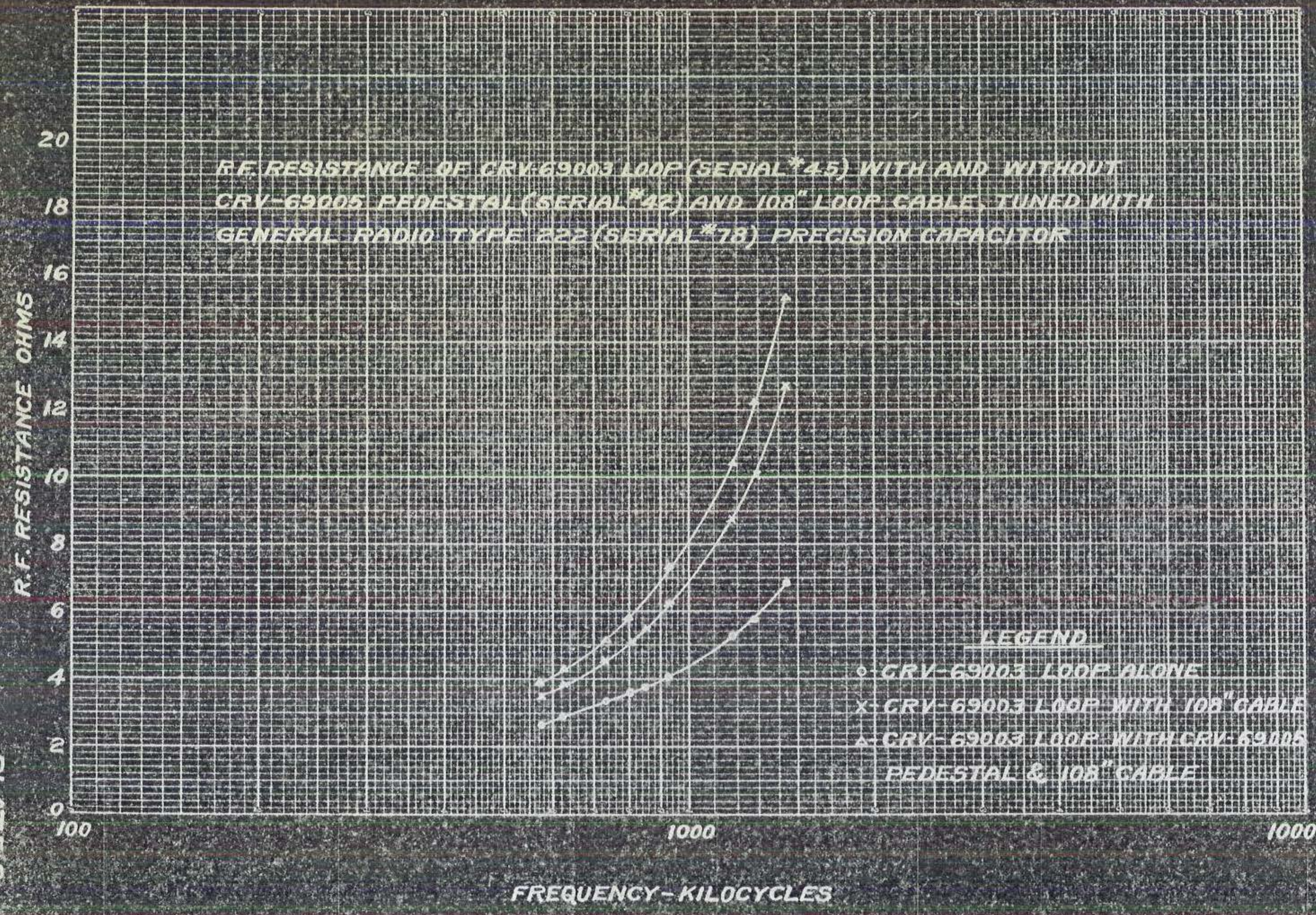
R.F. RESISTANCE OF CRV-69003 LOOP (SERIAL #45) WITH AND WITHOUT
CRV-69005 PEDESTAL (SERIAL #42) AND 108" LOOP CABLE, TUNED WITH
GENERAL RADIO TYPE 222 (SERIAL #78) PRECISION CAPACITOR
R.F. RESISTANCE OHMS
0
2
4
6
8
10
12
14
16
18
20
100
1000
10000
FREQUENCY - KILOCYCLES
LEGEND
○ CRV-69003 LOOP ALONE
× CRV-69003 LOOP WITH 108" CABLE
△ CRV-69003 LOOP WITH CRV-69005
PEDESTAL & 108" CABLE

PLATE 2

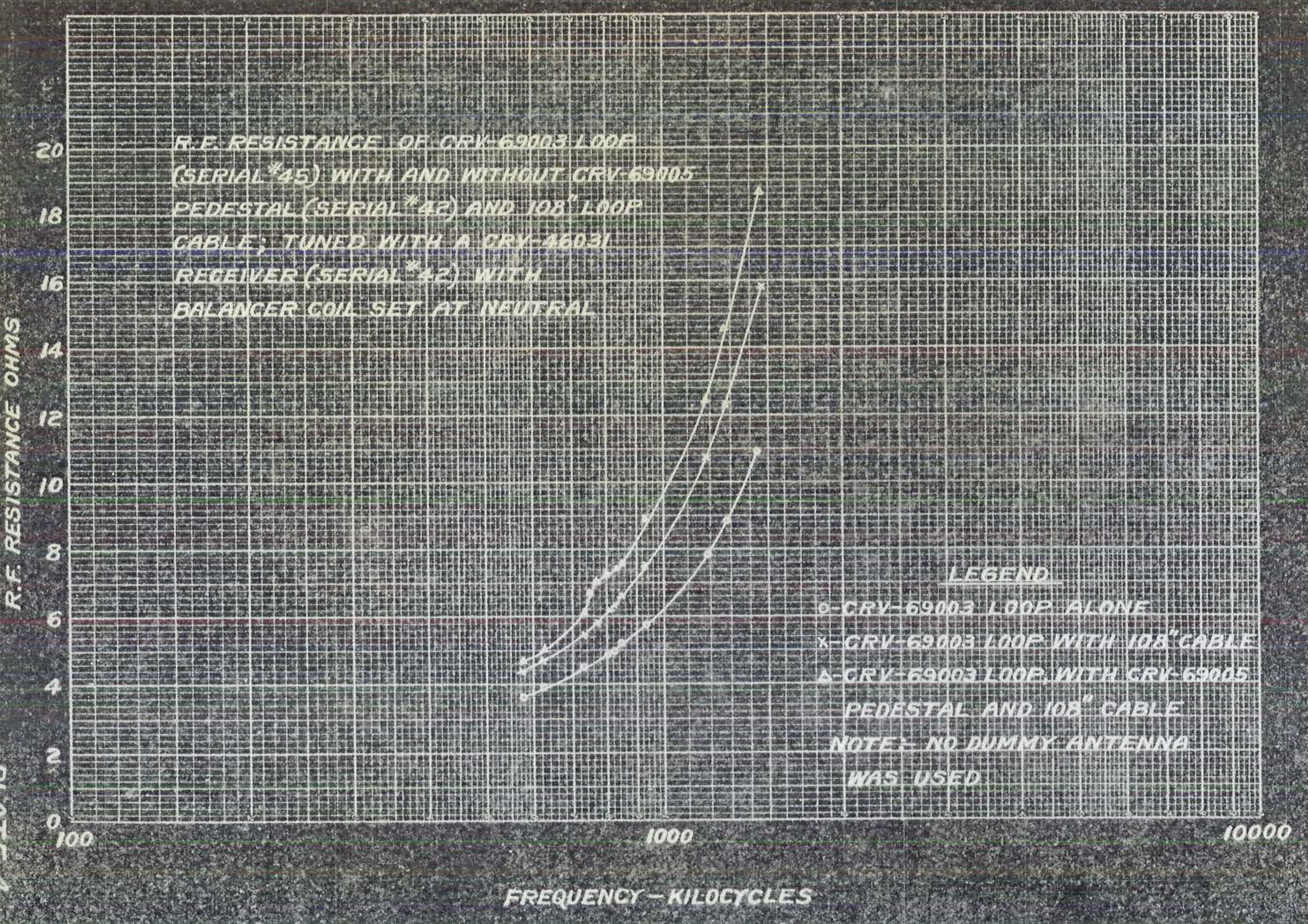
R.F. RESISTANCE OF CRV-69003 LOOP
(SERIAL #45) WITH AND WITHOUT CRV-69005
PEDESTAL (SERIAL #42) AND 108" LOOP
CABLE; TUNED WITH A CRV-46031
RECEIVER (SERIAL #42) WITH
BALANCER COIL SET AT NEUTRAL
R.F. RESISTANCE OHMS
0
2
4
6
8
10
12
14
16
18
20
100
1000
10000
FREQUENCY – KILOCYCLES
LEGEND
o-CRV-69003 LOOP ALONE
x-CRV-69003 LOOP WITH 108" CABLE
Δ-CRV-69003 LOOP WITH CRV-69005
PEDESTAL AND 108" CABLE
NOTE:- NO DUMMY ANTENNA
WAS USED

PLATE 4

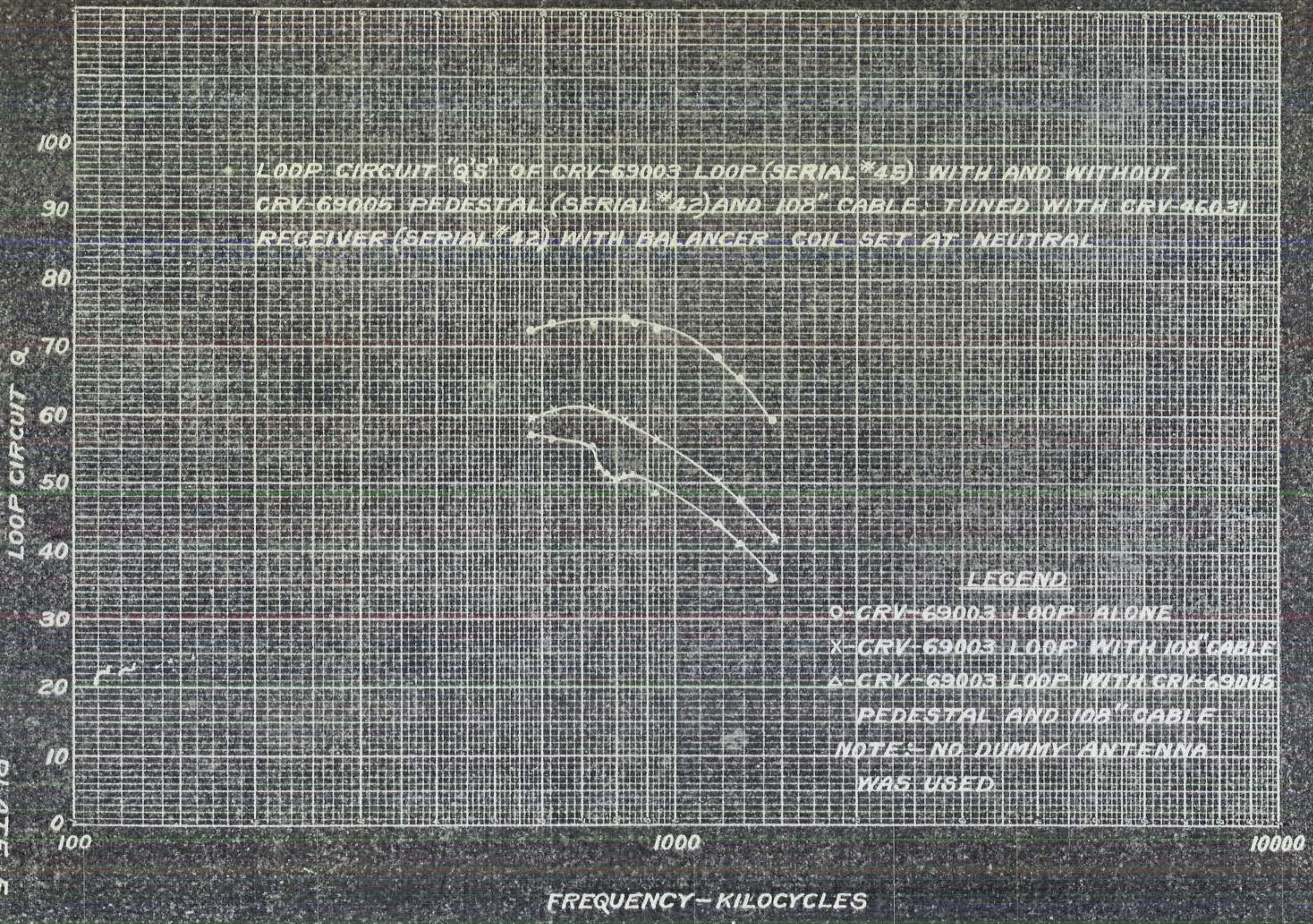
LOOP CIRCUIT "Q'S" OF CRV-69003 LOOP (SERIAL #45) WITH AND WITHOUT CRV-69005 PEDESTAL (SERIAL #42) AND 108" CABLE. TUNED WITH CRV-46031 RECEIVER (SERIAL #42) WITH BALANCER COIL SET AT NEUTRAL
LEGEND
O-CRV-69003 LOOP ALONE
X-CRV-69003 LOOP WITH 108" CABLE
△-CRV-69003 LOOP WITH CRV-69005 PEDESTAL AND 108" CABLE
NOTE:- NO DUMMY ANTENNA WAS USED
LOOP CIRCUIT Q
FREQUENCY - KILOCYCLES
0
10
20
30
40
50
60
70
80
90
100
100
1000
10000

PLATE 5

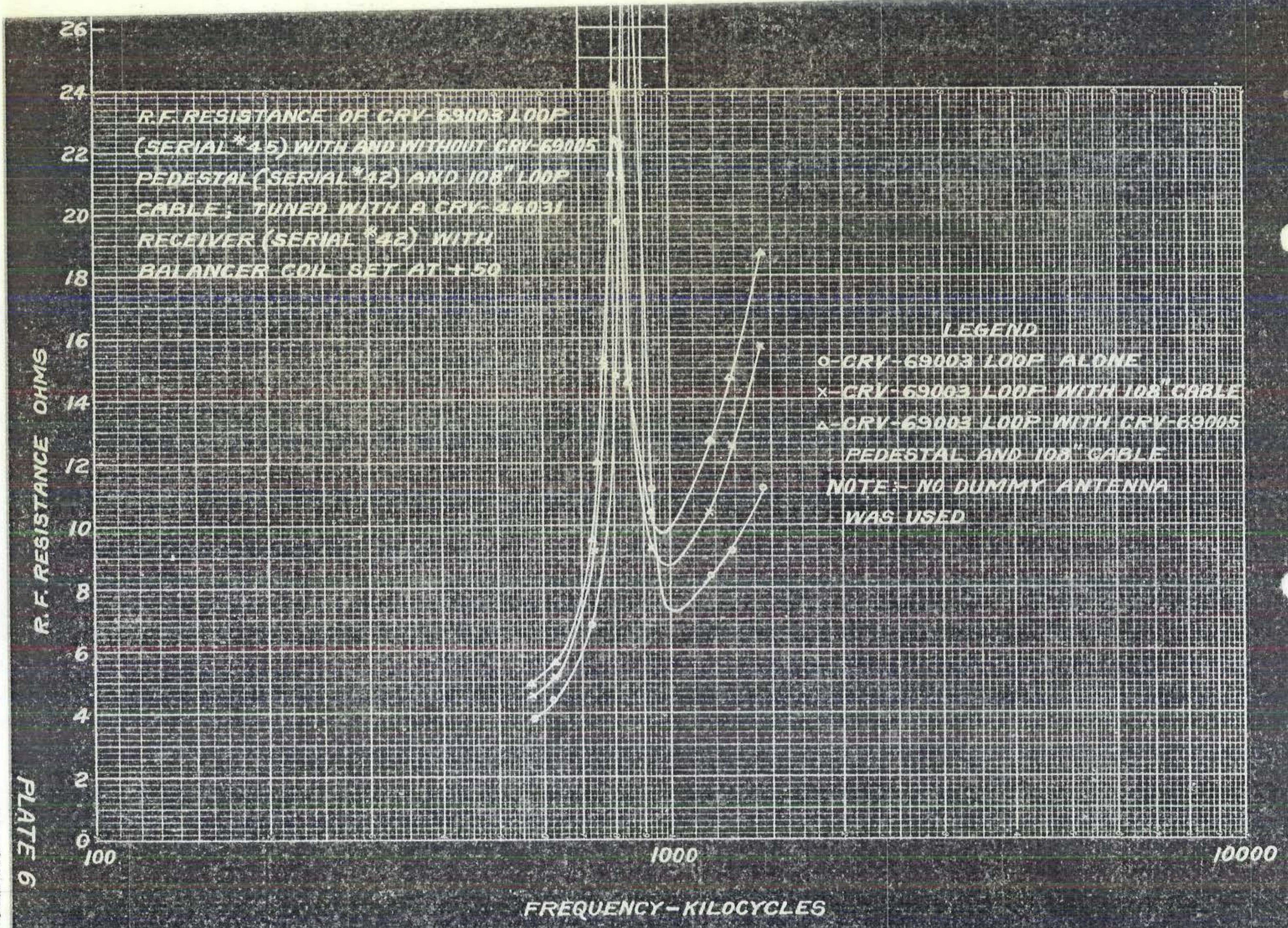
R.F. RESISTANCE OF CRV-69003 LOOP
(SERIAL *45) WITH AND WITHOUT CRV-69005
PEDESTAL (SERIAL *42) AND 108" LOOP
CABLE; TUNED WITH A CRV-46031
RECEIVER (SERIAL *42) WITH
BALANCER COIL SET AT +50
LEGEND
o-CRV-69003 LOOP ALONE
x-CRV-69003 LOOP WITH 108" CABLE
△-CRV-69003 LOOP WITH CRV-69005
PEDESTAL AND 108" CABLE
NOTE:- NO DUMMY ANTENNA
WAS USED
R.F. RESISTANCE OHMS
0
2
4
6
8
10
12
14
16
18
20
22
24
26
100
1000
10000
FREQUENCY-KILOCYCLES

PLATE 6

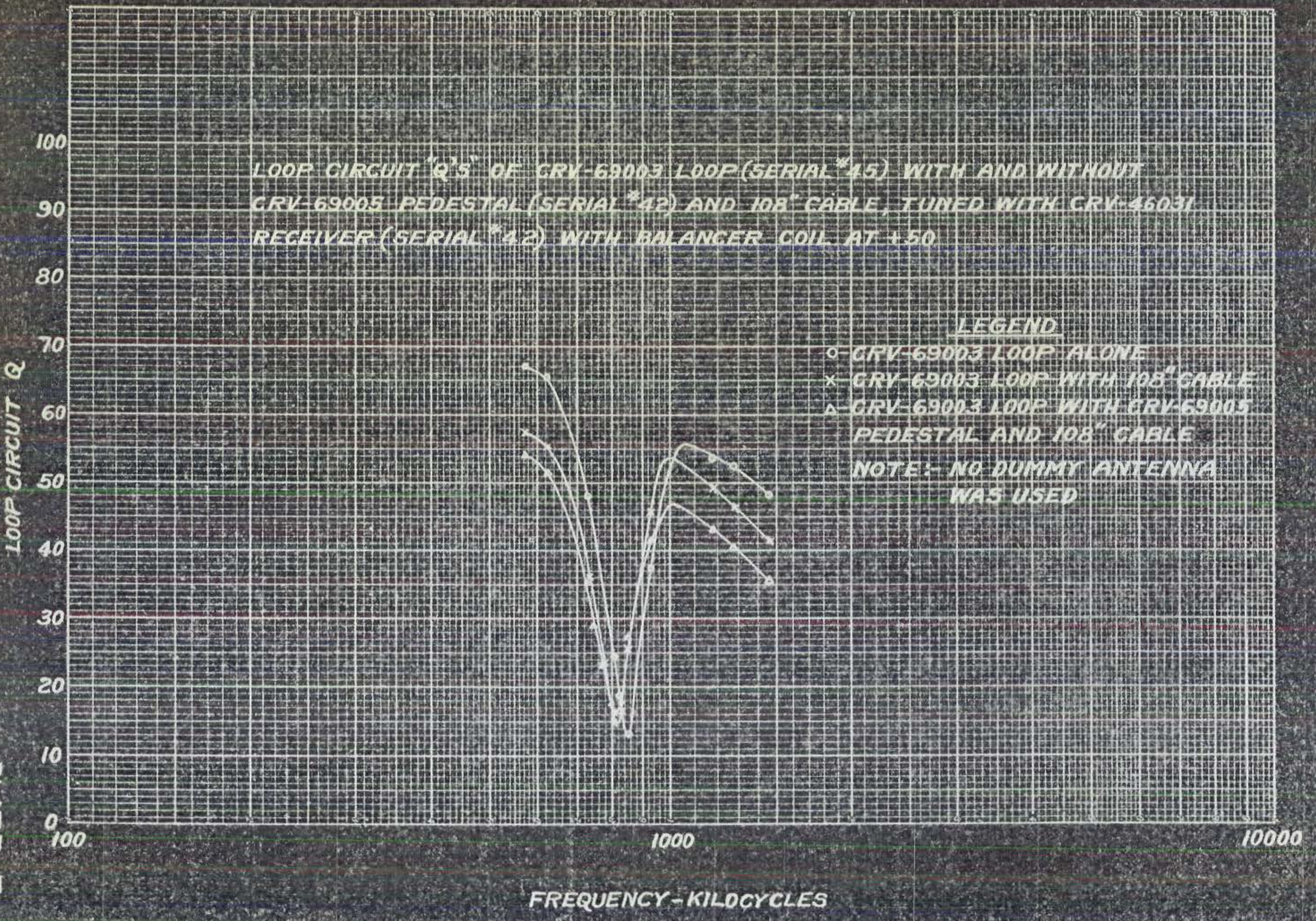
LOOP CIRCUIT "Q'S" OF CRV-69003 LOOP (SERIAL #45) WITH AND WITHOUT
CRV-69005 PEDESTAL (SERIAL #42) AND 108" CABLE, TUNED WITH CRV-46031
RECEIVER (SERIAL #42) WITH BALANCER COIL AT +50
LEGEND
○-CRV-69003 LOOP ALONE
×-CRV-69003 LOOP WITH 108" CABLE
△-CRV-69003 LOOP WITH CRV-69005
PEDESTAL AND 108" CABLE
NOTE:- NO DUMMY ANTENNA
WAS USED
LOOP CIRCUIT Q
0
10
20
30
40
50
60
70
80
90
100
100
1000
10000
FREQUENCY - KILOCYCLES

PLATE 7

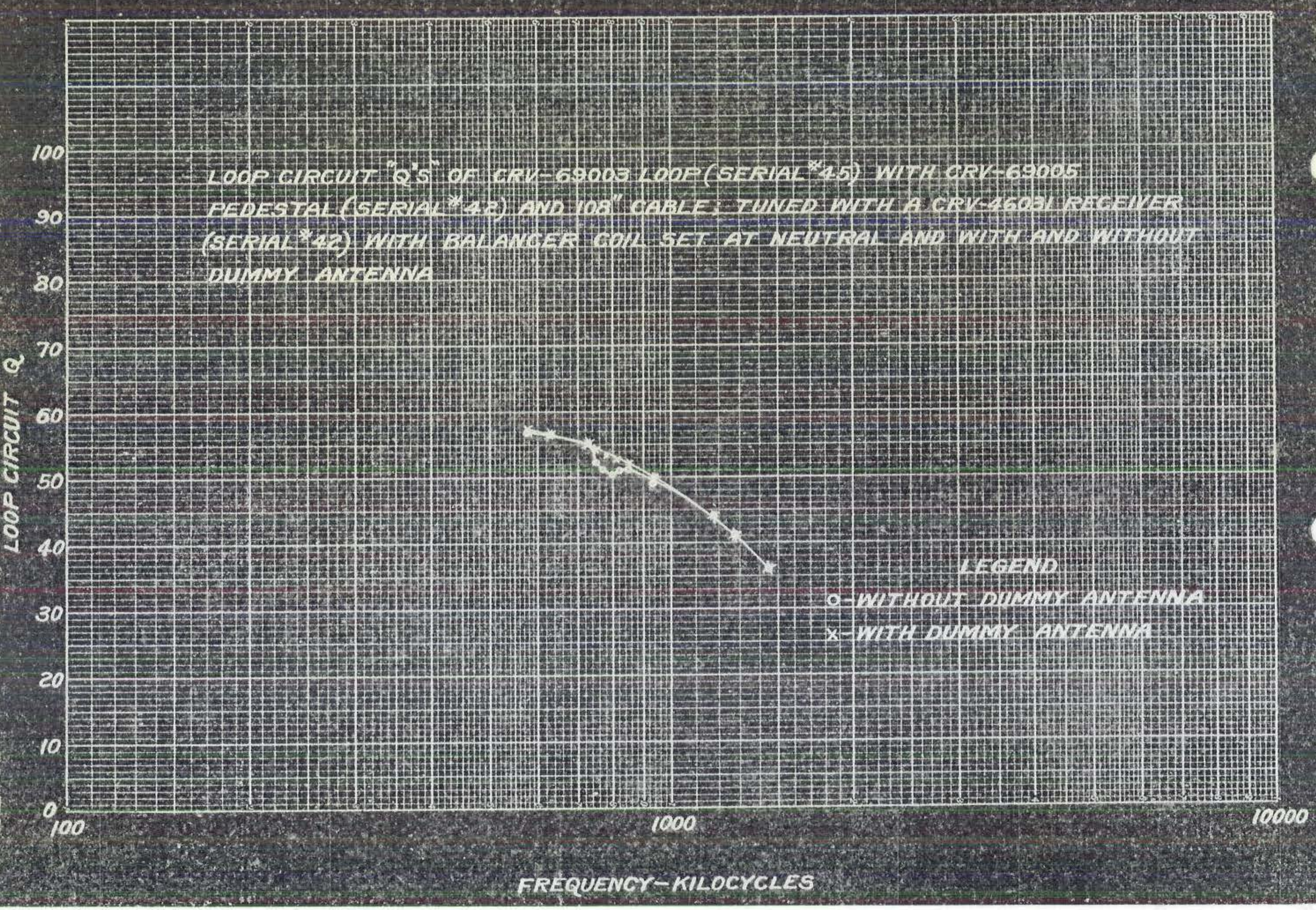
LOOP CIRCUIT "Q'S" OF CRV-69003 LOOP (SERIAL #45) WITH CRV-69005 PEDESTAL (SERIAL #42) AND 108" CABLE; TUNED WITH A CRV-46031 RECEIVER (SERIAL #42) WITH BALANCER COIL SET AT NEUTRAL AND WITH AND WITHOUT DUMMY ANTENNA
LEGEND
o-WITHOUT DUMMY ANTENNA
x-WITH DUMMY ANTENNA
LOOP CIRCUIT Q
0
10
20
30
40
50
60
70
80
90
100
100
1000
10000
FREQUENCY-KILOCYCLES

PLATE 9

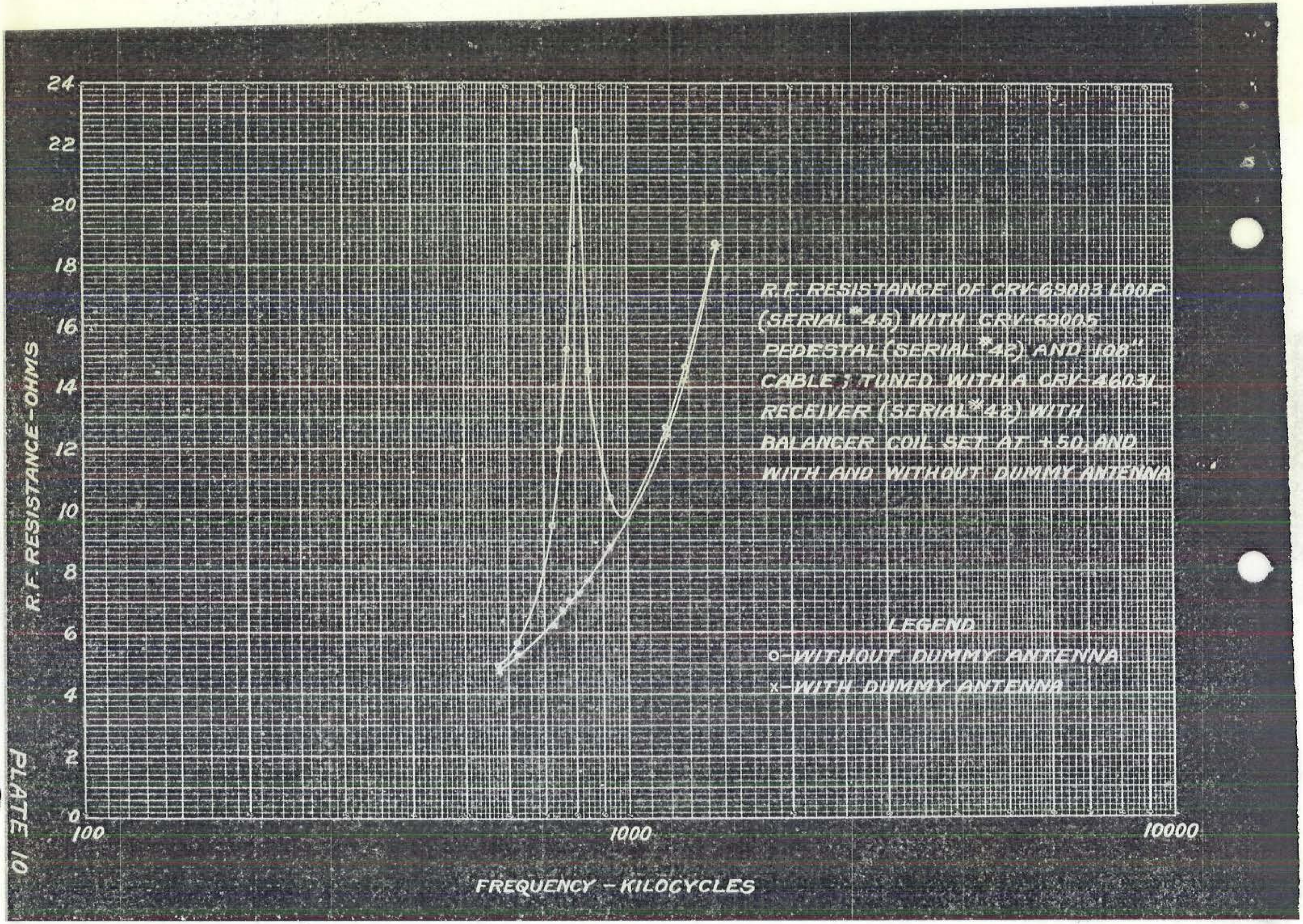
R.F. RESISTANCE OF CRV-69003 LOOP (SERIAL * 45) WITH CRV-69005 PEDESTAL (SERIAL * 42) AND 108" CABLE; TUNED WITH A CRV-46031 RECEIVER (SERIAL * 42) WITH BALANCER COIL SET AT +50, AND WITH AND WITHOUT DUMMY ANTENNA
LEGEND
o-WITHOUT DUMMY ANTENNA
x-WITH DUMMY ANTENNA
R.F. RESISTANCE-OHMS
FREQUENCY - KILOCYCLES
0
2
4
6
8
10
12
14
16
18
20
22
24
100
1000
10000

PLATE 10

AUTHORIZATION FOR TEST

1. The tests herein reported were authorized by reference (a). Other pertinent data are listed as references (b) to (e) inclusive.

Reference: (a) BuEng. let. S67/69/L5(4-10-W8) of 16 Apr. 1935.
(b) NRL Report No. R-1134.
(c) NRL Report No. R-1141.
(d) Specifications RE 13A 474A.
(e) Specifications RE 69A 175A.

OBJECT OF TEST

2. The object of these tests is to determine first, the extent to which the "Q's" of the CRV-69003 or CRV-69014 loops are influenced by reaction within their associated receiver circuits; second, the "Q's" of these same loops under the conditions as noted in par. (3) below; third, the accuracy of the radio frequency resistance measurements as reported in references (b) and (c), and fourth, the defects in the Models DO, DO-1, DO-2, and DO-3 loop and pedestal assemblies which have developed subsequent to the completion of reference (b).

ABSTRACT OF TEST

3. The tests conducted and reported herein are as follows:

(a) Measurement of the true inductance and distributed capacitance of first, the CRV-69003 loop; second, the CRV-69003 loop with its associated 108" loop-receiver cable, and third, the CRV-69003 loop with the CRV-69005 pedestal assembly and the 108" loop-receiver cable.

(b) Measurement of the radio frequency resistance of first, the CRV-69003 loop; second, the CRV-69003 loop and its associated 108" loop-receiver cable, and third, the CRV-69003 loop with the CRV-69005 pedestal and 108" loop-receiver cable; the loop being tuned with a precision capacitor for each test condition.

(c) Same as (b) except with the loop tuned with a CRV-46031 receiver, without the use of a standard balance antenna and with the balancer coil set at neutral.

(d) Same as (c) except with the balancer coil set at +50.

(e) Same as (c) but with the receiver employing a standard dummy antenna.

(f) Same as (d) but with the receiver employing a standard dummy antenna.



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with the male end of an ordinary receptacle so that it could be plugged into the female end of a receptacle connected to the lead from the loop center or to a similar receptacle which was shorted, this latter receptacle being required for obtaining the initial bridge balance for each frequency at which measurements were made. The "unknown" terminals of the radio frequency bridge were connected to a 50 ohm resistor and an 0.001 microfarad condenser in series. The "detector" terminal of the radio frequency bridge was connected to the antenna and ground terminals of an RAA-1 or RAB-1 receiver (depending upon the frequency) with a triple shielded conductor, the shield of which served as the low potential return. The output terminals of the loop, or loop and loop-receiver cable, or loop, pedestal, and loop cable, whichever unit or combination of units was concerned with a particular test, was then connected to the CRV-46031 receiver or precision condenser as required for tuning purposes.

8. The test set up as described in the foregoing affords a means for determining the radio frequency resistance of the unloaded or loaded loop circuit by the substitution method and a means for determining the true inductance and distributed capacitance of the loop circuit. In these tests, the loop terminals are at equal potential above ground, while the loop housing, pedestal frame and cable shield are at ground potential. The common ground connection was made from the standard signal generator case to the shielded booth.

9. The test procedures as described below apply to the loop, loop pedestal, and loop receiver cable normally assembled together. Repeat runs were made for the loop and cable direct connected together and then for the loop alone.

(a) Unloaded Loop Circuit. In this test, the loop circuit was tuned with the General Radio Type 222 precision condenser. The following steps were followed in making the tests.

(1) The RAA-1 or RAB-1 receiver, depending upon the frequency, was tuned to the frequency to which the standard signal generator was adjusted.

(2) The cable to the loop center from the radio frequency bridge was disconnected from the loop and shorted at the loop end.

(3) The radio frequency bridge was adjusted for balance by adjusting the decade resistance arm to balance the fixed resistance in the "unknown" arm; and adjusting the power factor and capacitance controls to balance the inserted capacitance in the "unknown" arm and the capacitance of the cable to the loop center. The setting of the decade resistance was then noted.

(4) The "short" was removed from the loop bridge cable and the cable connected to the loop center. Attention is called to the fact that by shorting the loop-bridge cable at the loop end, its constants are included in the initial adjustment of the radio frequency bridge and hence do not enter into the measurement of the

figures as given in ref. (b) for the loop receiver cable and pedestal leads were applied to ref. (c) and appear in par. 20 of that reference. It will be noted that these figures do not agree with the corresponding figures derived from Plate 1 appended hereto. It will be noted also that the total distributed capacitance of the Model DO loop, pedestal, and cable combination and shown on Plate 4 of ref.(b) is 150 micromicrofarads which is greater than that shown on Plate 1 of this report by 30 micromicrofarads. The following discussion will explain the reasons for this discrepancy and will apply to ref.(c) as well as (b) for it will be noted that on Plate 4 of ref. (c) the total distributed capacitance of the Model DQ loop and its pedestal and loop-receiver cable is 130 micromicrofarads.

22. The procedure described for determining the wave length squared curves for the subject equipment permits very precise tuning of the loop. Hence the results shown on Plate 1 of this report are more nearly correct than for those shown on Plate 1 of refs. (b) or (c). In these latter instances the loop was tuned with a precision condenser at the receiver end of the loop receiver cable. The test radio frequency signal was fed from a standard signal generator directly into the loop center and resonance was indicated by a "slide back" type of vacuum tube voltmeter bridging the precision condenser. Now while this method is satisfactory it is less precise than the bridge method owing to the fact that one cannot detect the absolute point of resonance by this visual means as by the oral means afforded by the bridge method. It is reasonable to assume that the error in determining the point of resonance by the visual method would be constant for all frequencies, but this error, probably as much as ± 5% in terms of tuning capacity, would be sufficient to change the slope of the wave length square curve by such an amount as to indicate a higher distributed capacitance for the loop circuit than actually exists. Since the distributed capacitances of Models DO loop as reported in ref. (b) and that of Model DQ loop as reported in ref. (c) were measured under the same precedure, it is reasonable to assume that the same difference between their distributed capacitances would continue to exist if they were both obtained by the bridge method. Hence, by this reasoning if the distributed capacitance of the total loop circuit as determined in the subject tests for the Model DO loop is 120 micromicrofarads, that of the Model DQ loop would be 100 micromicrofarads.

23. The above explanation for the discrepancies may well be applied to the discrepancies found in the calculations for true loop circuit inductance.

24. The distributed capacitances of the CRV-69005B pedestal and 108" cable used for the tests in ref.(b) were measured on a General Radio Type 650A impedance bridge. In making these measurements the two leads were not at equal potential with respect to ground and therefore do not simulate actual operating conditions and as a result the capacity measurements must be somewhat in error. It will be noted that the measurement of the distributed capacitance of the CRV-69005B pedestal lead as determined by the method described in ref.(b) is 33.9 micromicrofarads, whereas for the distributed capacitance of the CRV-69005 pedestal leads as determined from the wave length squared curves shown on Plate 1 of this report is 32 micromicrofarads. In this latter instance, both of the leads in the pedestal are at equal potential above ground and the pedestal housing is at



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