28 March 1935

NRL Report No. R-1141
BuEng. Prob. D1-7

NAVY DEPARTMENT

BUREAU OF ENGINEERING

Report on

# Test of Loop Structure Assembly

# of the

# Model DQ Radio Direction Finder Equipment

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ANACOSTIA STATION
WASHINGTON, D. C.

Number of Pages: Text - 8. Plates - 7

Authorization: BuEng let.S67/69(1-19-W8) of 22 January 1935.

Dates of Test: 7 March to 11 March; 18 March to 20 March 1935.


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Distribution: BuEng (4)

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AUTHORIZATION FOR TEST

1. The tests herein reported were authorized by ref.(a). Other pertinent data are listed as refs. (b) to (i) inclusive.

Reference: (a) BuEng Let.S67/69(1-19-W8) of 22 January 1935.
(b) Specifications RE 69A 175A.
(c) Specifications RE 13A 474A.
(d) Specifications RE 10A 263H (name plates)
(e) Specifications RE 13A 317F (ceramic insulating materials).
(f) NRL Report No. R-1134 of 13 March 1935.
(g) RCA Mfg.Co. Instruction Book IB-20-206.
(h) RCA Mfg.Co. Memo dated 20 February 1935.
(i) Contract NOs-38492 dated 3 October 1934.

OBJECT OF TEST

2. The object of this test was to determine first, the acceptability of the details incorporated in the complete loop and loop mounting structure as designed to be furnished with the Model DQ radio direction finder equipment and; second, its compliance with the governing specifications, refs.(b) and (c).

ABSTRACT OF TEST

3. The loop and loop mounting structure of the Model DQ equipment was set up in the Laboratory and given a general inspection for mechanical construction. In view of the fact that the receiver used with this equipment is the same as that employed with the Model DO-1 equipment, only the loop characteristics of the Model DQ equipment were determined. With this data, together with the performance data as given for the Model DO-1 equipment in ref.(f), the overall performance of the Model DQ equipment may be predetermined, on a comparative basis, since only the loop circuit characteristics of the two equipments will differ from one another. The electrical tests conducted are as follows:

(a) Determination of effective height of the loop within the range of 100 to 1500 kilocycles.

(b) Measurement of loop circuit radio frequency resistance.

(c) Determination of loop circuit Q's.

(d) Determination of loop circuit selectivity.

(e) Measurement of true inductance and distributed capacitance.

(f) Comparison between the Models DQ and DO-1 loops for loop circuit gain.

Conclusions

The conclusions of this report are confined to the design, construction, and operation of the complete loop assembly. In regard to overall performance of the Model DO radio direction finder equipment, consult the conclusions given in ref.(f).

(a) The complete loop assembly is considered to be very well constructed both electrically and mechanically. It presents a pleasing appearance, and the workmanship and materials employed are of excellent quality.

(b) The complete loop assembly when operated with a type CRV-46031A receiver and a type CRV-20011A power unit can be expected to yield results equal to those of the Model DO-1 equipment.

(c) The governing specifications have been met except as indicated under par.42 of this report which requires very slight mechanical changes, and as indicated in ref.(f).

Recommendations

It is recommended:

(a) That an improved means be provided for securing the dome for the azimuth dial lamp to avoid any possibility of its loss under conditions of vibration.

(b) That at least size #10-32 screws be employed for securing the collector ring brush assembly to the operating assembly of the loop equipment.

(c) That the loop antenna terminal plugs be made of suitable size to permit their insertion through the receptacle holes as provided in the types CRV-46031 or 46031A receivers.

(d) That the loop constants be made such as to assure that positive trimming may be obtained with the trimmer condensers as furnished in the CRV-46031A receivers.

(e) That the complete Model DO equipment be considered satisfactory for Naval service after the pertinent recommendations as listed above, and as listed in ref.(f), have been complied with in a manner meeting the approval of the Bureau of Engineering.

DESCRIPTION OF MATERIAL UNDER TEST

4. The material under test consisted of one complete loop and loop mounting structure as designed for use with the Model DQ radio direction finder equipment. No receiver was furnished. However, since the Model DQ receiver is to be the same as the Model DO-1 receiver, the latter was used for these tests. The Model DQ loop and loop mounting structure was manufactured by the RCA Manufacturing Company of Camden, New Jersey, on Contract NOs-38492 and was delivered to the Laboratory on 25 February 1935. The equipment as supplied included one CRV-69014 loop and loop shaft assembly, one CRV-69016 pressure hull fitting, one CRV-69017 collector ring assembly, one pedestal with the necessary parts for attaching to the hull and superstructure and for supporting the loop and drive.

METHOD OF TEST

5. The effective heights of the CRV-69014 loop assembly were calculated for 100 and 1500 kilocycles from the physical constants of the loop. Since the variation of the effective height of the loop with frequency is a linear relationship, calculations are required for only the upper and lower limiting frequencies.

6. The loop circuit radio frequency resistance was measured for five frequency settings for each band of the CRV-46031A receiver (Model DO-1). The loop was connected to the CRV-46031A receiver so as to furnish proper loading at all frequencies and a means for tuning the loop to resonance at the test frequencies. Measurements of radio frequency resistance were made with a General Radio Type 516C, Serial No.23, radio frequency bridge, using a General Radio Type LC-a, Serial No.1, standard signal generator as the signal source to the bridge and an auxiliary experimental receiver to indicate the null point. The substitution method of measurement using the bridge to indicate balance was applied to this test.

7. The loop circuit Q was calculated for the several frequencies at which radio frequency resistance measurements were made. The calculation for any frequency was based on the measured radio frequency resistance and the true inductance of the loop and load circuit at that frequency. A description of the method used for determining the true inductance of the loop and loop connecting leads down to the receiver input terminals is given below. The inductance of the load coils for each band of the CRV-46031A receiver was previously determined, and a description of the method employed for obtaining this data is given in ref.(f).

8. The loop circuit selectivity was calculated from the calculated Q values obtained for the overlap frequencies and geometric mean frequency of the overlap frequencies for each band of the CRV-46031A receiver. These calculations are based on the Universal Resonance Curve as found in Terman's "Radio Engineering".

9. The true inductance and distributed capacitance of the loop and loop connecting leads down to the receiver input terminals of the loop cable were determined by applying a signal from a General Radio Type LC-a standard signal generator to the loop center and then tuning the circuit

for resonance with a General Radio Type 222, Serial No. 162, precision condenser connected across the receiver input terminals of the loop cable. A Naval Research Laboratory slide back tube voltmeter connected across the receiver input terminals of the loop cable was used to indicate resonance. The capacity required to tune the loop to resonance was determined for several input signal frequencies. From this data a curve of wave length squared plotted as ordinates against capacity as abscissae may be obtained. The true inductance and distributed capacitance may then be calculated from data obtained from this curve.

10. A comparison of loop circuit gain when using one or the other of the Models DQ or DO-1 loops connected to the CRV-46031A receiver was made. For this test the loops were arranged with their planes parallel to each other and in such a position with respect to surrounding objects that the field intensity would be approximately the same for both. The DQ loop was connected to the receiver and a signal near the high frequency end of the high frequency band of the receiver was tuned in. The loop trimmer capacitor in the receiver was adjusted for maximum output. The Model DO-1 loop was then connected to the receiver input replacing the DQ loop and the above procedure for receiver adjustment repeated. The outputs obtained for both loops were then recorded.

DATA RECORDED DURING TESTS

11. Complete data were recorded on all tests conducted and this information is contained in Plates 1 to 7 appended hereto.

PROBABLE ERRORS IN RESULTS

12. Since the accuracy of the frequency adjustment of the standard signal generator is within ± 0.1% for all frequencies and since the accuracy of the radio frequency bridge is ± 1% for all values of resistances within the range of the bridge, the probable error in the results of the radio frequency measurements will depend very largely upon the slope of the radio frequency resistance curve for the loop circuit and upon the method of measurement. Inasmuch as the slope of the radio frequency resistance curve is not very steep, the error in the frequency adjustment will have only a slight effect upon the true radio frequency of the loop circuit at any frequency. The substitution method of measuring the radio frequency resistances eliminates the error of the bridge to a large extent. In the final analysis, the measured radio frequency resistances are within ± 0.1 ohm at any frequency.

13. The accuracy of the calculations for Q at any frequency is within the limits of ± 1%.

14. The loop circuit selectivity as calculated from the calculated Q for any frequency is accurate to ± 10% for sensitivities off resonance.

15. The errors introduced in determining the effective heights of the loop depend upon the symmetry of the loop winding within the loop housing. In all probability, these calculations are accurate to within 5%.

16. These calculations of the true loop inductance and distributed capacitance of the loop and its associated leads are accurate to within ± 10 %, as determined from the wave length squared curve.

RESULTS OF TESTS

17. The calculation of the effective heights of the CRV-69014 loop at 100 and 1500 kilocycles is based on the formula:

$$h = \frac{w\,a\,N}{3} \times 10^{-12}$$

where h = effective height in meters,

a = area of loop in square centimeters,

N = number of turns,

w = 2 π f, where f = frequency in cycles.

The loop is wound with 8 turns of stranded cotton braid insulated, tinned copper wire having a diameter equivalent to #16 B&S gauge. The mean diameter of the loop is 52.0 centimeters. The effective height of the loop varies from 0.00350 to 0.0534 meter for a frequency range of 100 to 1500 kilocycles respectively. This is slightly less than for the Model DO-1 loop (CRV-69003) whose effective height varies from 0.00387 to 0.0581 meter for the same frequency range. A curve showing this relationship is shown on Plate 1.

18. The radio frequency resistances of the CRV-69014 loop are shown on Plate 2. Comparing these results with those shown for the Model DO-1 loop (Plate 6, ref.(f) ), it will be noted that the resistances are approximately the same for the two types of loops near the low frequency ends of each band but that they increase more rapidly with frequency for the CRV-69014 loop than for the CRV-69003 loop. It will be noted also that the curve for the high frequency band shows the same irregularity as does the corresponding curve for the CRV-69003 loop, but to a much greater degree. This irregularity was checked and rechecked without change in results.

19. The loop circuit Q's shown on Plate 3 were calculated from the radio frequency resistance values shown on Plate 2 and the true inductance of the loop circuit at the several frequencies considered by applying the following formula:

$$Q = \frac{wL}{R}$$

where L = loop circuit inductance (includes loop and load coil inductance in millihenries),

R = radio frequency resistance of loop circuit in ohms,

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

Comparing the loop circuit Q's of the CRV-69014 loop with those shown on Plate 9, ref.(f), for the CRV-69003 loop, it will be noted that the Q's are approximately the same near the low frequency end of each band but decrease more rapidly near the high frequency ends of the low frequency and medium frequency bands for the former loop than for the latter. This is in agreement with the results obtained and discussed under par.18 above. The decided irregularity of the curve for the high frequency band reverts back to that of the radio frequency resistance curve for the same band. On the average, however, the loop circuit Q's for the Model DQ equipment are slightly less than for the Model DO-1 equipment.

20. Plate 4 shows the wave length squared curve for determining the true inductance and distributed capacitance of the CRV-69014 loop together with its associated pedestal leads, slip rings, and receiver coupling cable. The calculated inductance is 64.3 microhenries and is 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 curve,

3.553 = a constant.

This compares with the calculated inductance of 63.2 microhenries for the Model DO-1 equipment. The distributed capacitance as determined by the distance from the origin to the intercept of the curve with the axis of abscissae is 130 micromicrofarads. This compares with a value of 150 micromicrofarads for the Model DO-1 equipment. Since by a previous measurement the distributed capacitance of the 108" cable is 103 micromicrofarads, this leaves a value of 17 micromicrofarads for the loop, loop pedestal, and slip rings. The capacitance of the loop, loop pedestal, and slip rings for the Model DO-1 equipment was 46.5 micromicrofarads. The reduction in the overall distributed capacitance of the Model DQ loop equipment is due largely to the use of ceramic insulation (presumably isolantite) which is used throughout the assembly.

21. The loop circuit selectivity curves shown on Plates 5, 6, and 7, are based on the calculated loop circuit Q's and the Universal Resonance Curve shown in Terman's "Radio Engineering".

22. A comparison of the loop circuit gain shows the Model DQ loop equipment to be approximately 4 decibels better than for the Model DO-1 equipment under similar conditions of test. In connection with this test, it is to be noted that it was possible to trim the loop circuit of the CRV-46031A receiver to match the Model DQ loop with the minimum capacitance setting of the loop trimmer condenser, thus leaving no tolerance for cases where the LC of the loop may be greater than in the model tested.

23. The results obtained from the tests made on the Model DQ loop equipment and discussed under pars.17 to 22 inclusive show that the performance of the Model DQ radio direction finder equipment will be very closely the same as for the Model DO-1 radio direction finder equipment. Therefore, further tests on the former equipment for specification compliance will be unnecessary, and the results of the tests conducted on the latter equipment and covered in NRL Report No. R-1134, ref.(f), will apply to the subject equipment. Briefly, then, it may be stated that the Model DQ equipment will comply with specifications, ref.(c), only to the same extent as does the Model DO-1 equipment. All paragraphs except pars.5-1 to 5-37 inclusive and 13-1 to 13-6 inclusive of Specifications RE 13A 474A, applying particularly to the Model DO-1 equipment and reported upon in ref.(f), apply equally well to the Model DQ equipment.

24. The following comments are with reference to Specifications RE 61A 175A, ref.(b), which apply directly to the construction and operation of the Model DQ loop assembly structure. Reference should be made here to the preliminary instruction book, IB-20-206, ref.(g), for detail drawings of the subject equipment and instructions for installing the loop and drive. The Model DQ equipment falls under the classification of group "E"equipment as defined in ref.(b).

25. Par. 1, 2 (groups A to D), 3, 4, 8 to 20 inclusive, 23 to 33 inclusive, and 41 to 58 inclusive do not apply to group "E" equipments. Par.5 to 7 inclusive, 21, 22, and 34 to 40 inclusive, apply directly to group "E" equipments and are covered by the reference paragraphs below.

26. Par. 2 (group "E"). No radio receiver or power unit for the Model DQ equipment was received at the Laboratory for test.

27. Par. 59, 60. Specification requirements are met.

28. Par. 61. No comment.

29. Par. 62. All above deck parts of the Model DQ loop other than wire or insulating material are of brass. The pedestal and deck clamps are finished with a heavy galvanizing which is suitable for taking paint after installation. The loop castings and loop shaft, except for the cover end, are coated with clear glyptal varnish as part of the sealing operation. It is claimed by the manufacturer that this coating serves as a satisfactory base for any suitable paint after installation. Glazed ceramic insulating material, probably isolantite, has been used wherever insulation is required. All bolts, nuts, and lock washers exposed to sea water are stainless steel.

30. Par.63. No test as prescribed by this specification was conducted at the Laboratory. It was stated, however, in the RCA memorandum, ref.(h), that the loop and loop shaft assembly for the Model DQ equipment had been subjected to a hydrostatic pressure test at 350 pounds per square inch intermittently applied after assembly. The results of this test are, however, not recorded.

31. Par. 64, 65, 66. Specification requirements are met.

32. Par.67 (par.5, 6, 7) The CRV-69014 loop is a rotatable metallic brass tubular housing made up of three sections bolted together and with a winding for radio reception purposes contained within. The loop is circular in form, having a round cross section and is capable of rotating symmetrically in a circle having an extreme diameter of 23-3/4". The specification requirement in this regard is not more than 24" and not less than 22". The loop assembly is so constructed as to be watertight when mounted.

33. Par. 68, 69, 70, 71, 72. The requirements of these specifications are met.

34. Par. 73. (par.34, 35, 36, 38, 39) An azimuth scale having a diameter of 10" is provided and secured to the operating assembly. The azimuth scale carries on its periphery 1, 5, and 10 degree marks from 0 to 360 degrees, reading with increase of numerical values from left to right as viewed when installed for operation. Each tenth division is suitably marked with numerical figures. The marks from 0 to 191 degrees inclusive are filled in black, while those from 191 to 359 degrees inclusive are filled in red. The operating hand wheel provided for the purpose of rotating the loop has a diameter of 15 inches, is of the open rim type, and is designed to be firmly secured to the operating shaft. The rim of the hand wheel is of wood, finished with walnut varnish.

35. Par.74 (par.37). The requirements of these specifications are met.

36. Par.75 (par.21, 22). The requirements of these specifications are met.

37. Par.76. No comment.

38. Par.77, 78. The requirements of these specifications are met.

39. Par.79. The insulation of the loop and lead wires and the material of the spacer blocks are presumably of isolantite. Refer to Plate 3 for the Q values of the loaded loop at any frequency within the range of 100 to 1500 kilocycles. No measurements were made for the loop when unloaded.

40. Par.80. Specification compliance is met.

41. Par.81. A 9 foot shield cable similar to that furnished with the Model DO-1 equipment is provided for connecting the collector rings to the radio receiver.

42. A summary of the defects noted are as follows:

(a) Par. 74. The method for securing the dome for the azimuth scale lamp is not satisfactory owing to the fact that under conditions of vibration the thumb screw will become loosened, thus permitting the cam for securing the dome to shift its position and hence release the dome. The dome, when released, falls out of place very easily and is, thus far, very apt to become lost.

(b) Par.81. The screws for securing the collector brush assembly to the operating assembly are not in keeping with the rugged design of the rest of the loop structure. These screws should be at least size #10-32.

(c) The loop and antenna plugs differ from those furnished with the DO-1 equipments by having their metallic outer cases made of 1/16" instead of 1/32" tubing, thus making it impossible to fit them into the receptacle holes provided in the receiver cabinets as furnished with the DO-1 equipments.

(d) The loop constants are such that trimming is barely possible with the trimmer condensers provided in the receivers with which they may be expected to operate.

CONCLUSIONS

43. The conclusions of this report are confined to the design, construction, and operation of the complete loop assembly. In regard to overall performance of the Model DO radio direction finder equipment, consult the conclusions given in ref.(f).

44. The complete loop assembly is considered to be very well constructed both electrically and mechanically. It presents a pleasing appearance, and the workmanship and materials employed are of excellent quality.

45. The complete loop assembly when operated with a type CRV-46031A receiver and a type CRV-20011A power unit can be expected to yield results equal to those of the Model DO-1 equipment.

46. The governing specifications have been met except as indicated under par.42 of this report which requires very slight mechanical changes, and as indicated in ref.(f).

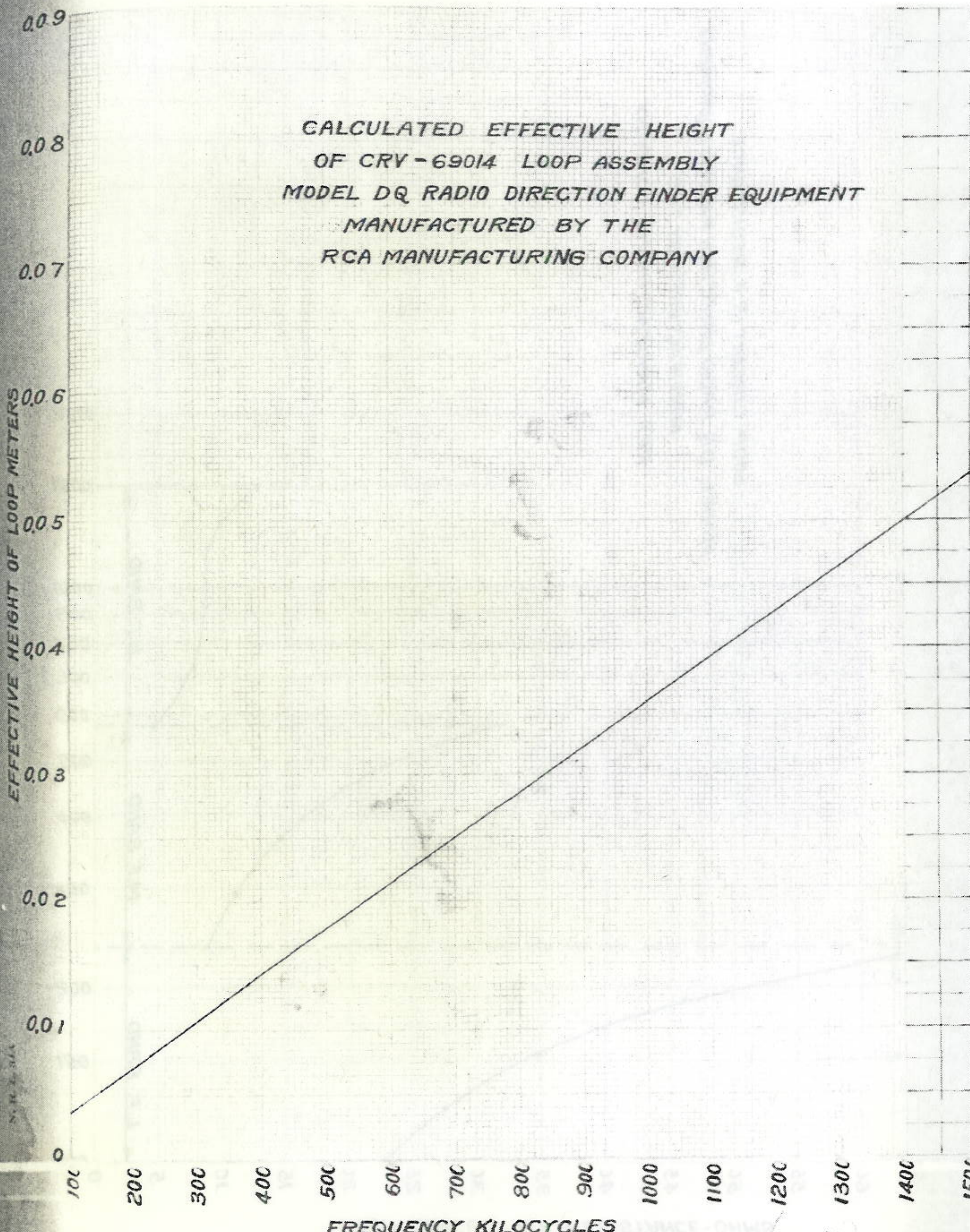

CALCULATED EFFECTIVE HEIGHT
OF CRV-69014 LOOP ASSEMBLY
MODEL DQ RADIO DIRECTION FINDER EQUIPMENT
MANUFACTURED BY THE
RCA MANUFACTURING COMPANY
EFFECTIVE HEIGHT OF LOOP METERS
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
FREQUENCY KILOCYCLES
200
300
400
500
700
1000
1100
1500

PLATE I

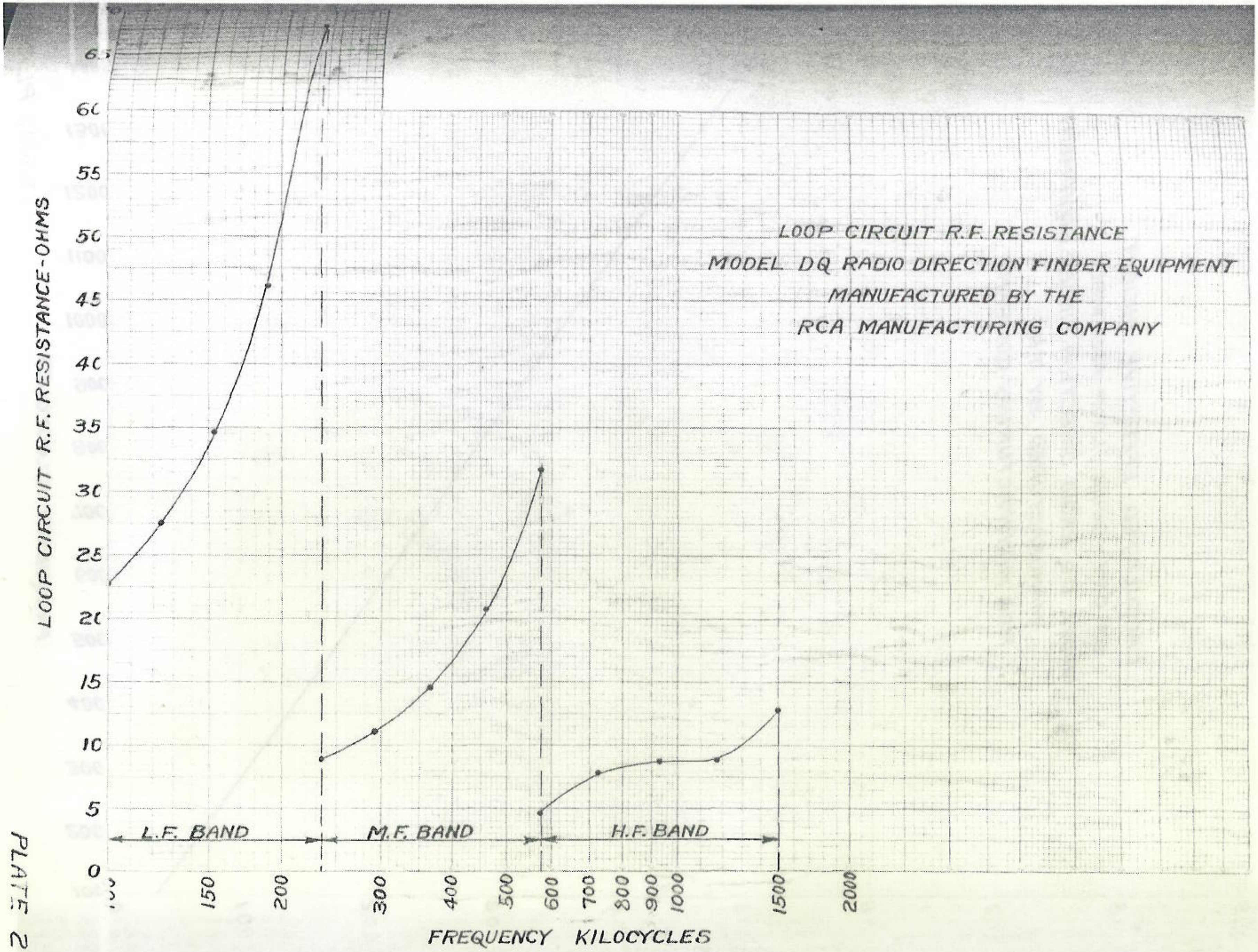

LOOP CIRCUIT R.F. RESISTANCE
MODEL DQ RADIO DIRECTION FINDER EQUIPMENT
MANUFACTURED BY THE
RCA MANUFACTURING COMPANY
LOOP CIRCUIT R.F. RESISTANCE-OHMS
0
5
10
15
20
25
30
35
40
45
50
55
60
65
L.F. BAND
M.F. BAND
H.F. BAND
150
200
300
400
500
600
700
800
900
1000
1500
2000
FREQUENCY KILOCYCLES

PLATE 2

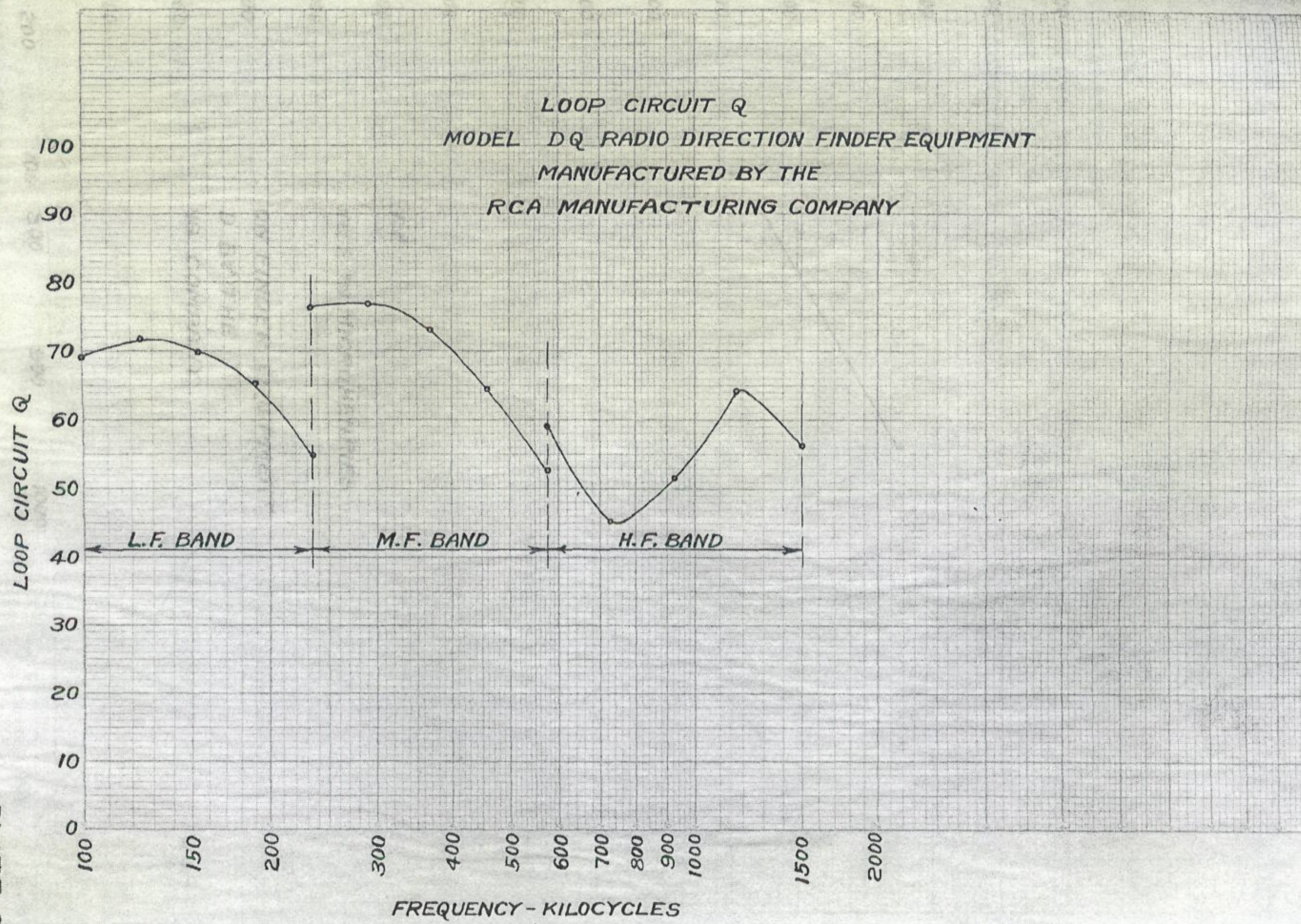
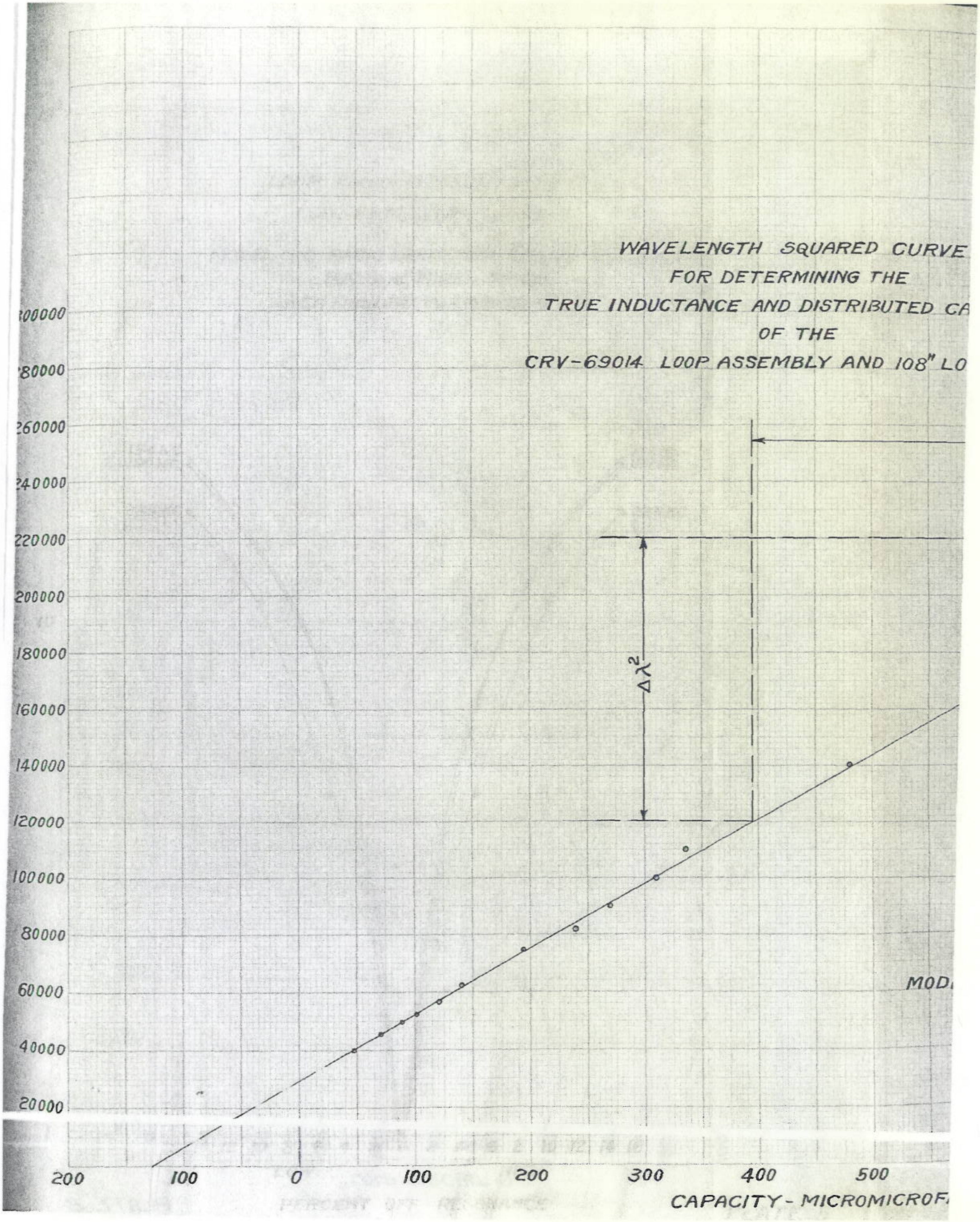
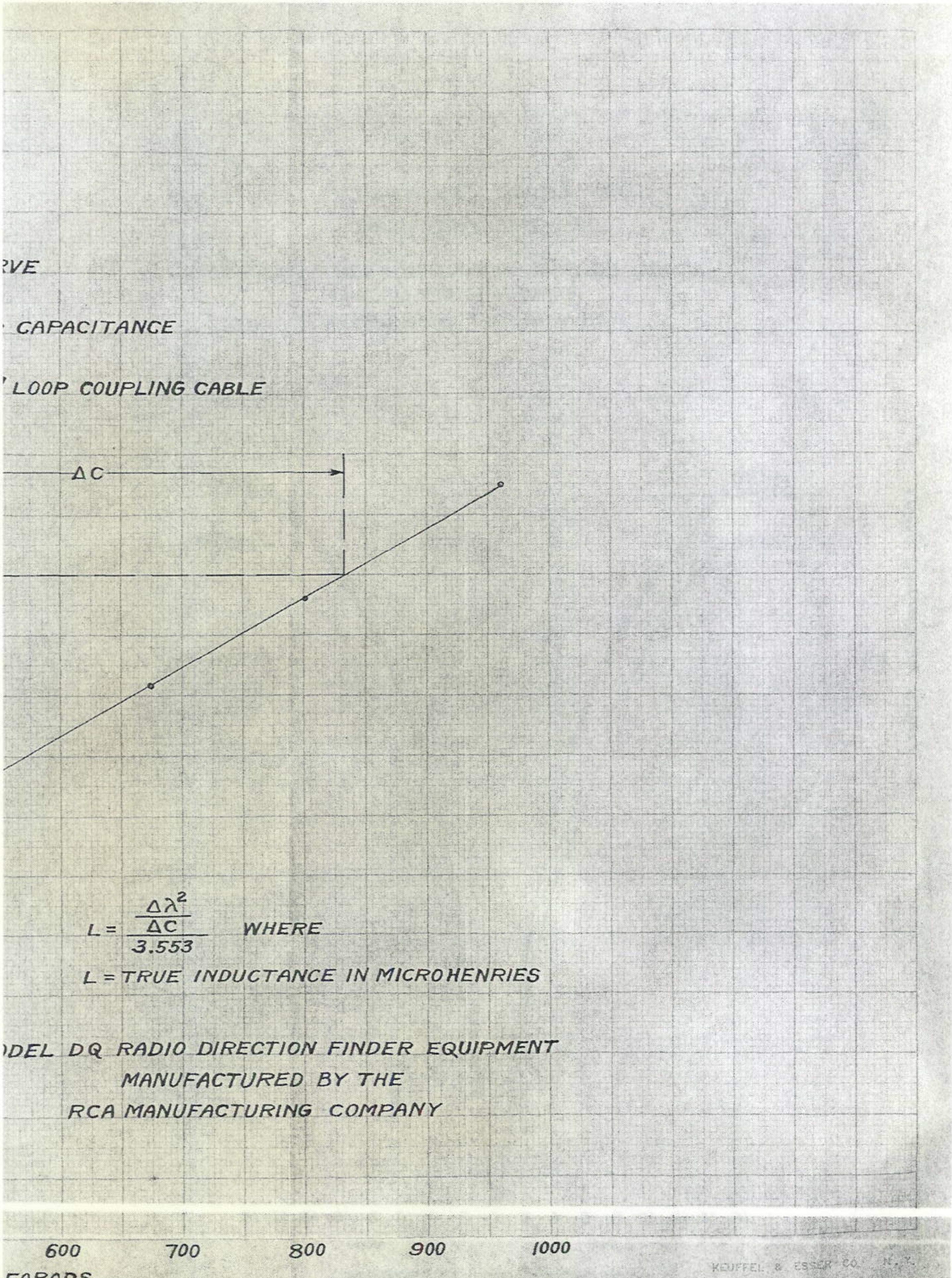

LOOP CIRCUIT Q
MODEL DQ RADIO DIRECTION FINDER EQUIPMENT
MANUFACTURED BY THE
RCA MANUFACTURING COMPANY
LOOP CIRCUIT Q
0
10
20
30
40
50
60
70
80
90
100
L.F. BAND
M.F. BAND
H.F. BAND
100
150
200
300
400
500
600
700
800
900
1000
1500
2000
FREQUENCY - KILOCYCLES

PLATE 3

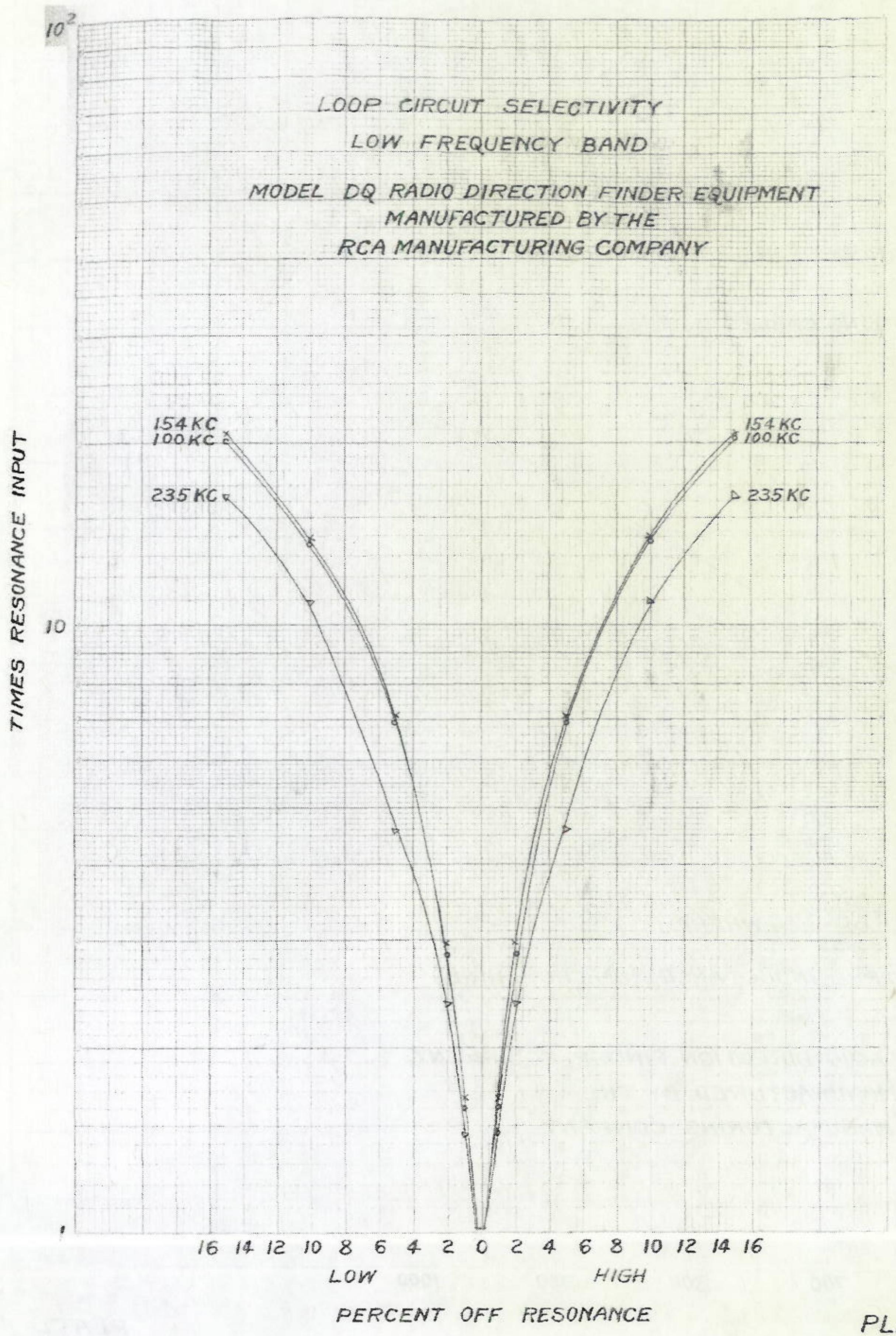


WAVELENGTH SQUARED CURVE
FOR DETERMINING THE
TRUE INDUCTANCE AND DISTRIBUTED CA
OF THE
CRV-69014 LOOP ASSEMBLY AND 108" LO
$\Delta\lambda^2$
MOD
200
100
0
100
200
300
400
500
CAPACITY - MICROMICROF
20000
40000
60000
80000
100000
120000
140000
160000
180000
200000
220000
240000
260000
280000
300000



RVE
CAPACITANCE
LOOP COUPLING CABLE
ΔC
$L = \frac{\frac{\Delta\lambda^2}{\Delta C}}{3.553}$ WHERE
L = TRUE INDUCTANCE IN MICROHENRIES
DEL DQ RADIO DIRECTION FINDER EQUIPMENT
MANUFACTURED BY THE
RCA MANUFACTURING COMPANY
600
700
800
900
1000
FARADS
KEUFFEL & ESSER CO. N. Y.


PLATE 4



LOOP CIRCUIT SELECTIVITY
LOW FREQUENCY BAND
MODEL DQ RADIO DIRECTION FINDER EQUIPMENT
MANUFACTURED BY THE
RCA MANUFACTURING COMPANY
$10^2$
10
1
TIMES RESONANCE INPUT
154 KC
100 KC
235 KC
154 KC
100 KC
235 KC
16 14 12 10 8 6 4 2 0 2 4 6 8 10 12 14 16
LOW
HIGH
PERCENT OFF RESONANCE


PLATE 5

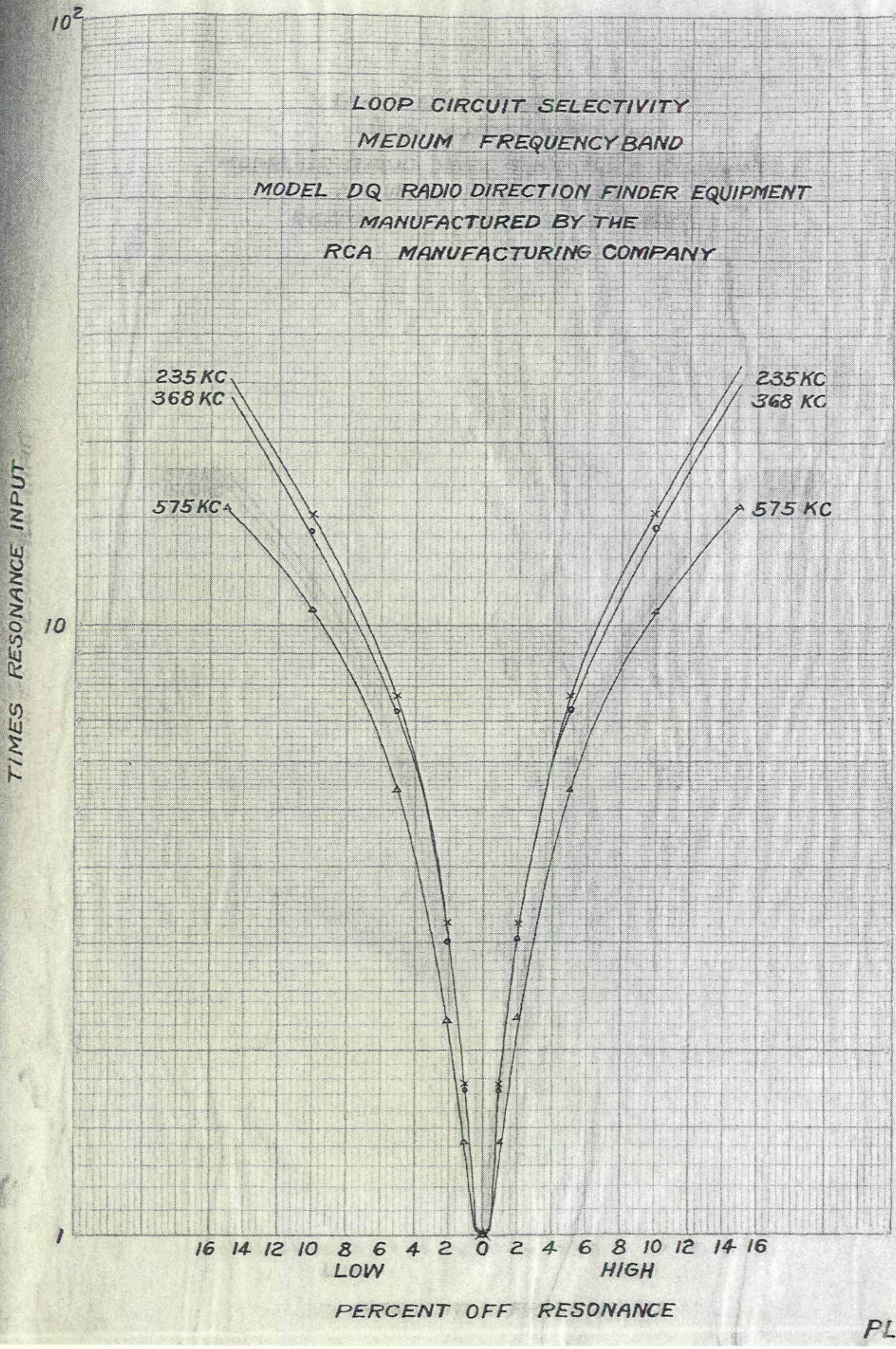
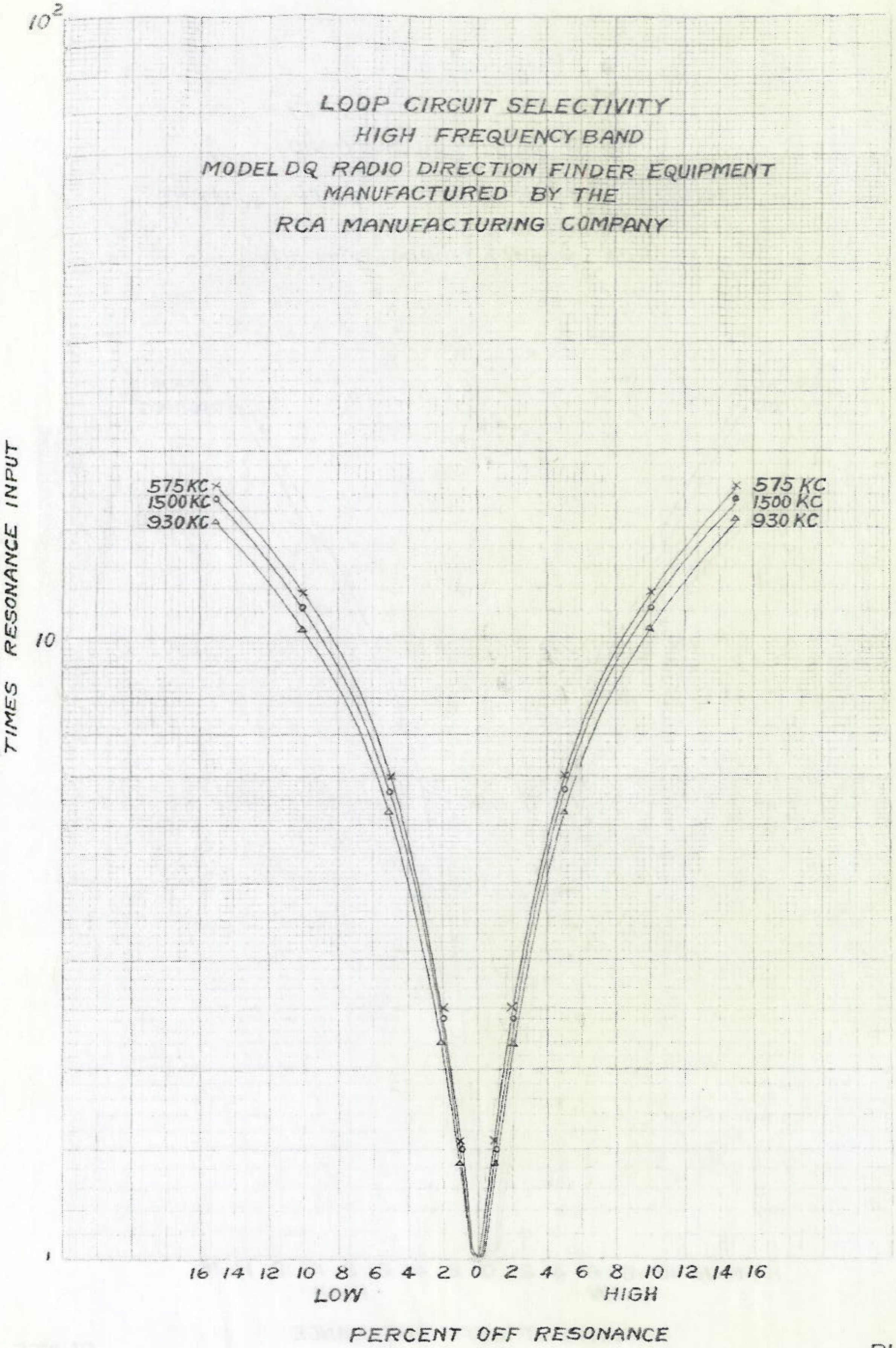

LOOP CIRCUIT SELECTIVITY
MEDIUM FREQUENCY BAND
MODEL DQ RADIO DIRECTION FINDER EQUIPMENT
MANUFACTURED BY THE
RCA MANUFACTURING COMPANY
235 KC
368 KC
575 KC
235 KC
368 KC
575 KC
TIMES RESONANCE INPUT
10²
10
1
16 14 12 10 8 6 4 2 0 2 4 6 8 10 12 14 16
LOW
HIGH
PERCENT OFF RESONANCE

PLATE 6



LOOP CIRCUIT SELECTIVITY
HIGH FREQUENCY BAND
MODEL DQ RADIO DIRECTION FINDER EQUIPMENT
MANUFACTURED BY THE
RCA MANUFACTURING COMPANY
575 KC
1500 KC
930 KC
575 KC
1500 KC
930 KC
$10^2$
10
1
TIMES RESONANCE INPUT
16 14 12 10 8 6 4 2 0 2 4 6 8 10 12 14 16
LOW
HIGH
PERCENT OFF RESONANCE


PLATE 7