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FR-2692

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SHIP-SHORE RADIO DIVISION - M. AND D. F. SECTION

21 December 1945

BALANCED INPUT SENSITIVITY MEASUREMENTS USING UNBALANCED SIGNAL GENERATORS

By S. F. George

- Report R-2692 -

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Declassification authority: NAVY DECLASS GUIDE/NAVY DECLASS MANUAL, 11DEC2012, OS SERIES

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S. G. Lutz - Head, M. and D. F. Section

L. A. Gebhard, Superintendent
Ship-Shore Radio Division

Commodore H. A. Schade, USN
Director, Naval Research Laboratory

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NRL Problem S1046R-C

B uncl

[redacted] Serial No. 25

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Classification changed from Unclassified
By CNO ltr Op-413-B23/ovk
Serial 203P413 dated 11/20/45

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ABSTRACT

The problem of measuring the sensitivity of balanced input radio receiving systems with an unbalanced (grounded) standard signal generator is considered for the frequency range 1.5-30 megacycles. Particular emphasis is placed on the sensitivity measurement of direction finder systems employing goniometers with center tapped stators grounded through resistors, often difficult to remove. Three different approaches are discussed: (1) the employment of resistive networks for maintaining a balance, (2) the employment of unbalanced to balanced transformers and (3) the removal of the center tap and measurement as an unbalanced system. Results indicate that all three methods can be made to yield results in agreement within the limits of experimental accuracy. Two shielded balanced-to-unbalanced transformers were built with balance ratios of better than 50 db and coefficients of coupling of 0.93 and 0.91 for the low and high frequencies respectively.

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INTRODUCTION

1. The problem invariably has arisen as to the correct method, for sensitivity measurements, of feeding the test signal from an unbalanced signal generator into a receiver system having a balanced input. Of particular importance in the field of direction finding is the sensitivity measurement through the balanced stator of an inductive goniometer. Considerable work is still being done by the Navy in the frequency range from 1.5 to 30 megacycles. Examples of equipments now in use are the Models DAQ and DAU shipboard installations and the DAJ-a shore arrays now employing DAU receiver and indicator equipment. It is therefore of considerable importance to the Navy to know just what laboratory tests on sensitivity of the systems can be relied upon to predict accurately the performance of the system in an actual installation. In laboratory investigations requiring the evaluation from sensitivity considerations of inductive goniometers for use in various installations, it is frequently impracticable, if not impossible, to provide a true dummy antenna during the tests. This may be the case especially where the antenna and transmission line constants vary considerably from one installation to another of the same type. For such cases, it has been the accepted practice to employ as the input impedance or dummy antenna a resistance equal to the characteristic impedance of the transmission line employed. While this does not give the same figure of sensitivity as would be obtained by using the correct dummy antenna for each case, it is considered a sufficiently accurate indication of average sensitivity.

STATEMENT OF PROBLEM

2. The problem involved the determination for the medium and high frequency bands of the correct methods which may be used in making sensitivity measurements on equipments having balanced inputs when employing unbalanced signal generators. Since the work was particularly directed toward measurements of direction finder equipments employing inductive goniometers, the text is written with this in view. This does not preclude the extension of the results and conclusions to a balanced input other than a goniometer, i.e., a receiver input directly. However, it is noted that the balanced input used for these tests was center tapped through 50 ohms to ground. Some of the results would be different should the center tap be grounded directly or through a different value of resistance. For any particular circuit being tested, the contribution of the size of resistance from center tap to ground to the errors of measurement may be determined by comparing methods A and E of Plate 1. The exact frequency range covered is 1.5 to 30 megacycles.

WORK PREVIOUSLY DONE ABOVE 20 MEGACYCLES

3. Research work of a similar nature above 20 megacycles had been previously reported by RCA (see Reference 2). In this report two methods were suggested for converting from an unbalanced signal generator to balanced output: (1) by balanced-to-unbalanced transformers and (2) by resistance pads. In addition twelve different unbalanced input circuits, used directly from an unbalanced signal generator, were tested. No sensitivity figures were given to afford a comparison between the two balanced methods and the twelve unbalanced input

[redacted]

circuits. However, of the twelve unbalanced input circuits tested, the greatest departure of any one from the average sensitivity figure of the twelve at 43 megacycles was only eight percent although the excursion of values covered a 20 percent change. In these tests, the only common ground between the signal generator and the receiver was through the power line.

COMMENTS ON TEST EQUIPMENT USED

4. The following is a list of the test equipment used:

(a) Model DAU (Serial #33) Receiver with Modified I-F Band Width of 3.4 kc (FTRC).

(b) Model DAU (Serial #33) Goniometer (FTRC).

(c) Model 65-B (Serial #708) Measurements Standard Signal Generator.

(d) Model 165-A (Serial #23077) RCA Junior Voltohmyst.

The Standard Signal Generator listed above has an output which is unbalanced, or grounded on one side. No signal generator is commercially available which has an output balanced to ground in the frequency range 1.5 to 30 megacycles. The test equipment and receiver were preheated to stability prior to the measurements. Since it is only a comparison between input systems that is required and not an absolute value for sensitivity, the absolute accuracy of the test equipment is not required but merely the repeatability of readings. The tests were necessarily conducted on different days, and the repeatability of the sensitivity readings was found to be within ± 10%. It is to be noted that the signal generator used necessarily had to be one in which the signal leakage was negligible or determinable.

METHOD OF MEASUREMENT

5. Two different methods of feeding the goniometer were investigated: (1) feeding the signal into one stator unbalanced and (2) feeding the signal into one stator balanced to ground. It might be pointed out here that by "unbalanced feeding" is meant feeding the signal directly from the unbalanced signal generator through the dummy load to the balanced input terminals. In some of the cases considered (see A, B, and C, Plate 1) it may actually simulate to a very close approximation a balanced condition at the input terminals especially when the center tap is not grounded directly. The stator being fed was in its position of maximum coupling to the rotor, the other stator which was left open being thus in a position of minimum coupling to the rotor (theoretically zero coupling). In all cases, the impedance looking back into the source was adjusted to equal as nearly as possible 140 ohms resistance across the balanced stator input terminals, this being the combined characteristic impedance of the twin-coaxial transmission line employed. The output of the receiver used was rectified i-f voltage from the second detector which meant that no modulation of the carrier was used. The sensitivities recorded were the microvolts input through 140 ohms required to produce a 20 db signal plus noise-to-noise ratio, with 10 volts standard d-c signal plus noise output. Three sets of frequencies were tested: (1) to repre-

 [redacted]

sent the medium frequencies 1.5 to 2 megacycles, (2) to represent the low end of the high frequencies 10 and 12 megacycles, and (3) to represent the upper end of the high frequencies 28 and 30 megacycles.

Unbalanced Input Circuits

6. The diagrams in Plates 1 and 2 show the test circuits used for measuring the sensitivities with unbalanced input. Circuits I through L although upon inspection obviously unuseable were tested because they have been used or advocated by various manufacturers. For all of these tests and through all six frequencies investigated the Measurements 65-B Standard Signal Generator was used. For this reason the output impedance of the signal generator is shown in the sketches as 5 ohms, which value obtains in the 65-B through 2 megacycles. The output impedance does vary from about 15 ohms at 10 to 12 megacycles to about 23 ohms at 28 to 30 megacycles. In these tests, however, the low frequency end of the band was considered the more important, and hence the 5 ohms was placed in the circuit diagrams. The grounds indicated on the diagrams represent connections to a common heavy braid ground strip, which also grounded the receiver chassis.

Balanced Input Circuits

7. In the absence of any signal generator with an output balanced to ground over the frequency range from 1.5 to 30 megacycles, it became necessary to employ some means of converting from an unbalanced signal generator to a balanced system having determinable output impedance and output voltage. To accomplish this, two balanced-to-unbalanced transformers were designed to test the sensitivities at the extremes of the frequency range studied. The transformer designated as #1 was used in a circuit which had an output impedance of very nearly 140 ohms pure resistance at 1.5 and 2 megacycles and a balance ratio over 50 db and the transformer designated as #2 was used in a circuit which had an output impedance of nearly 140 ohms pure resistance at 28 and 30 megacycles with a balance ratio of over 50 db. The balance ratio of the transformers was measured by the substitution method, first feeding from either one of the balanced terminals to ground and then feeding from the shorted balanced terminals to ground. Calling the first voltage V_1 and the second V_2, the balance ratio is given by the expression $20 \log_{10} \frac{V_1}{V_2}$. The open-circuited impedance of the transformers was determined both by calculation and measurement, the two being in very close agreement. The open-circuited voltage was found to be 1.2 times the signal generator output voltage for both transformers in the frequency range used. This was substantiated both by calculation and by two methods of measurement. The circuit diagrams for both transformers, with the actual circuit constants used, are given in Figures 1 and 2 of Plate 3. The transformer #2 is shown in Plate 4 at 1-1/2 times actual size.

RESULTS OF MEASUREMENTS

8. The numerical results of the sensitivity measurements are tabulated in Table 1. The letter headings refer to the test condition illustrated in the circuit diagrams of Plates 1 through 3. The sensitivity figures are expressed in microvolts of cw signal output through 140 ohms required to produce

[redacted]

a 20 db signal plus noise-to-noise ratio. It is very important to note here that the microvolt reading of sensitivity is not always the signal generator output reading, but it is defined as the open-circuited voltage in microvolts in series with the desired open-circuited impedance. In these measurements the signal generator used was calibrated for open-circuited voltage output, but a correction factor had to be applied when using the two transformers.

9. The figures given in column M and N of Table 1, which are obtained by using the two balanced-to-unbalanced transformers, will be considered the correct sensitivity values and will be used as basis of comparison. The average sensitivity figures of the unbalanced test conditions A, C, D, E, and F are given in the last column of Table 1. These average values vary from the correct balanced values by less than 5 percent at any frequency tested. The maximum excursion from the average of any sensitivity figure in columns A, B, C, D, E, and F does not exceed 10 percent.

CONCLUSIONS

10. In making sensitivity measurements in the frequency range from 1.5 to 30 megacycles upon the particular equipment tested, it is not necessary to use balanced-to-unbalanced transformers to convert the unbalanced signal generator voltages into balanced voltages. The signal may be fed unbalanced through the appropriate matching resistance using any one of the methods A, B, C, D, E, and F as illustrated in Plate 1 without errors greater than the expected experimental and equipment error.

11. In making sensitivity measurements in the frequency range from 1.5 to 30 megacycles upon equipments having balanced inputs in general, it should always be safe to use methods E and F in which the center tap has been removed. The chief disadvantage in these methods lies in the fact that it is frequently very inconvenient to remove the center tap.

12. Methods A, B, C, and D should yield accurate results provided there is a relatively large impedance from the center tap to ground. Of the four, method D is the least desirable and the accuracy of this method if proportional to the size of the center tap impedance. The four methods would be unuseable if the coil were center tapped directly to ground.

REFERENCES

1. BuShips confidential letter Serial No. 1435(925D) R&D25D-96 dated 14 February 1945 to NRL: Request for Assignment of Problem S1046R-C.

2. "Input Connections for U.H.F. Measurements", RCA License Division Bulletin LB-537 dated 9 October 1940.

3. BuShips undated memorandum for file on NRL conference of 24 April 1945 on Matters Relative to DAJ-a (Serial 976) Serial GM-976-1944.

4. NRL letter C-S67/69(301B), Serial C340-139/45 of 14 July 1945 to BuShips.

TABLE 1

SENSITIVITIES IN MICROVOLTS INPUT TO GIVE
A 20 DB SIGNAL-TO-NOISE RATIO

Frequency In Megacycles	Test Conditions (See Plates 1, 2, and 3)												Average of A,C,D,E,F	M&N
	A	B	C	D	E	F	G	H	I	J	K	L		
1.5	2.6	2.6	2.6	3.0	2.8	2.9	1.7	2.9	2.1	6.4	2.1	6.3	2.8	2.8
2.0	2.3	2.3	2.4	2.6	2.6	2.7	1.6	2.6	2.3	5.3	2.3	5.3	2.5	2.4
10.0	2.8	2.8	2.8	2.9	3.1	3.2	2.7	2.0	3.3	4.4	3.3	4.2	3.0	-
12.0	2.5	2.5	2.5	2.6	2.9	3.0	2.5	2.3	3.0	4.0	3.0	4.1	2.7	-
28.0	12.4	12.4	12.4	13.0	13.6	14.4	12.0	11.5	21.0	24.0	21.0	22.0	13.2	13.2
30.0	15.5	15.5	15.3	17.0	16.0	16.5	15.0	14.5	25.0	30.0	25.0	26.0	16.1	15.7

Useable Unbalanced Input Circuits

A

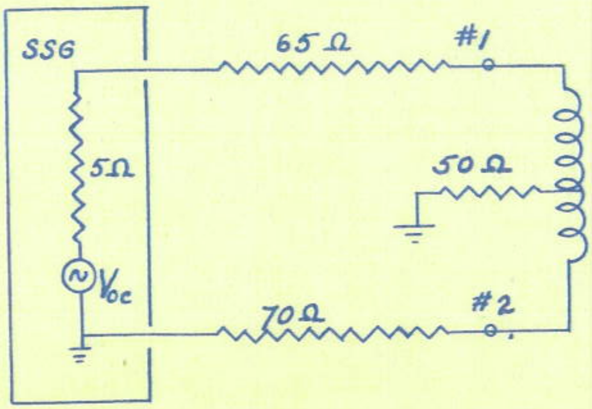


Fig. 1

B

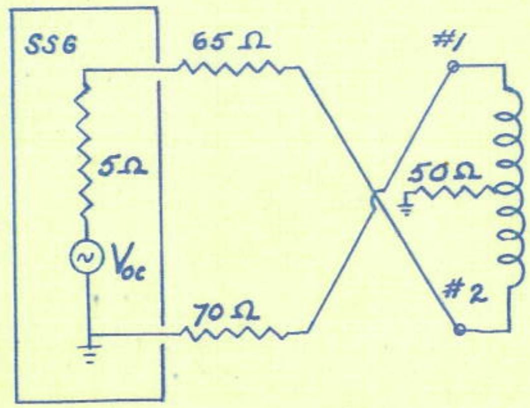


Fig. 2

C

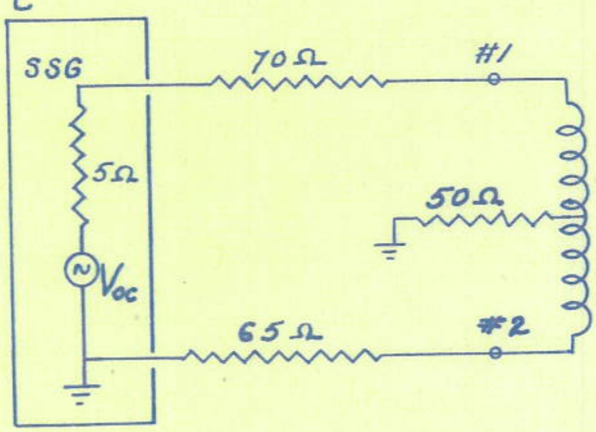


Fig. 3

D

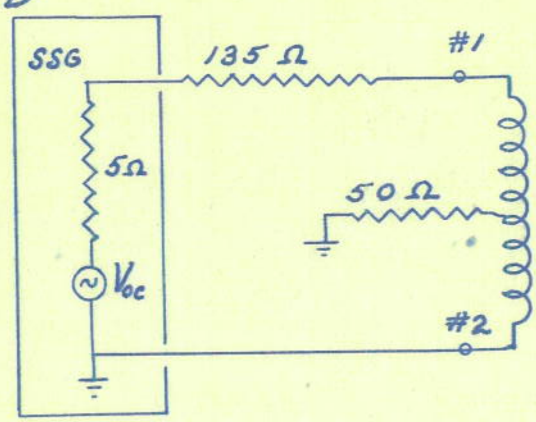


Fig. 4

E

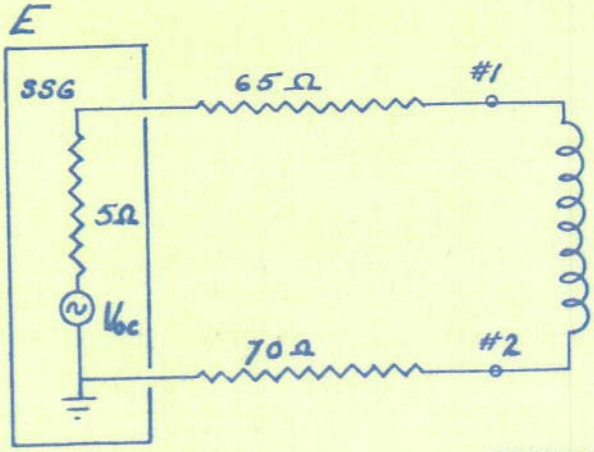


Fig. 5

F

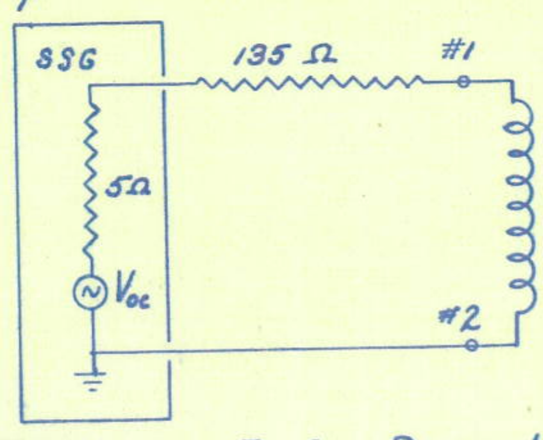


Fig. 6 Plate 1

UNUSEABLE UNBALANCED INPUT CIRCUITS

G

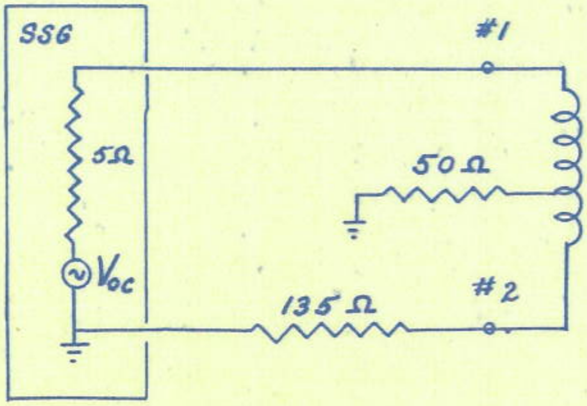


FIG. 1

H

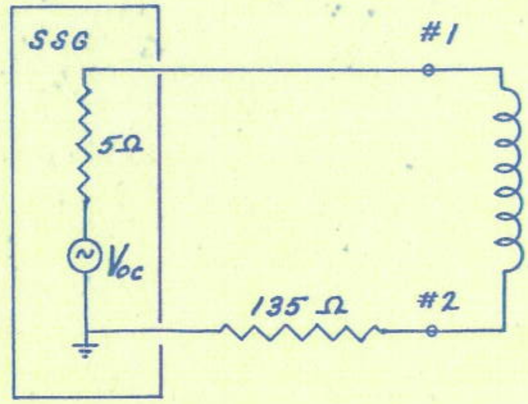


FIG. 2

I

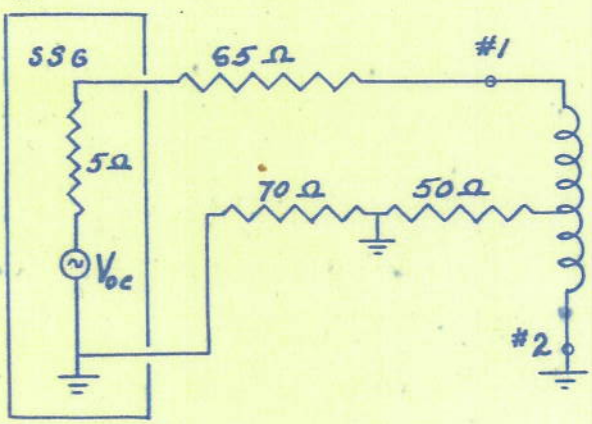


FIG. 3

J

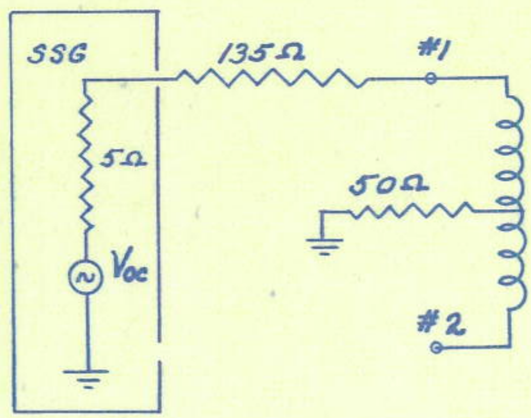


FIG. 4

K

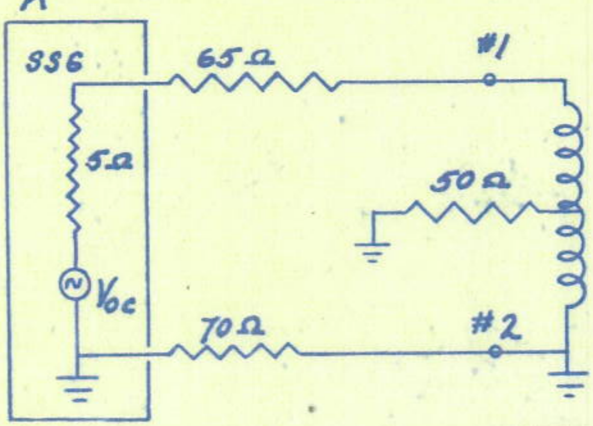


FIG. 5

L

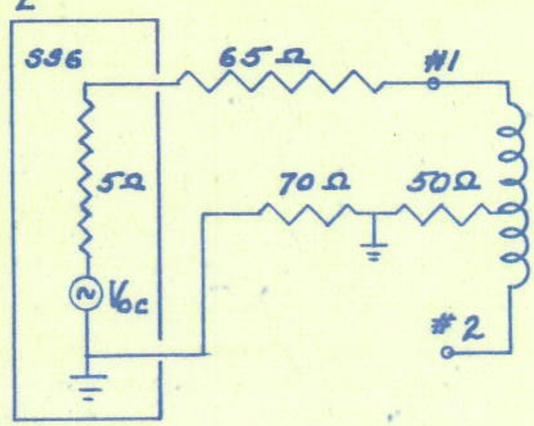


FIG. 6

PLATE 2

Balanced Input Circuits

M

Transformer 1.5 – 2 mcs (#1)

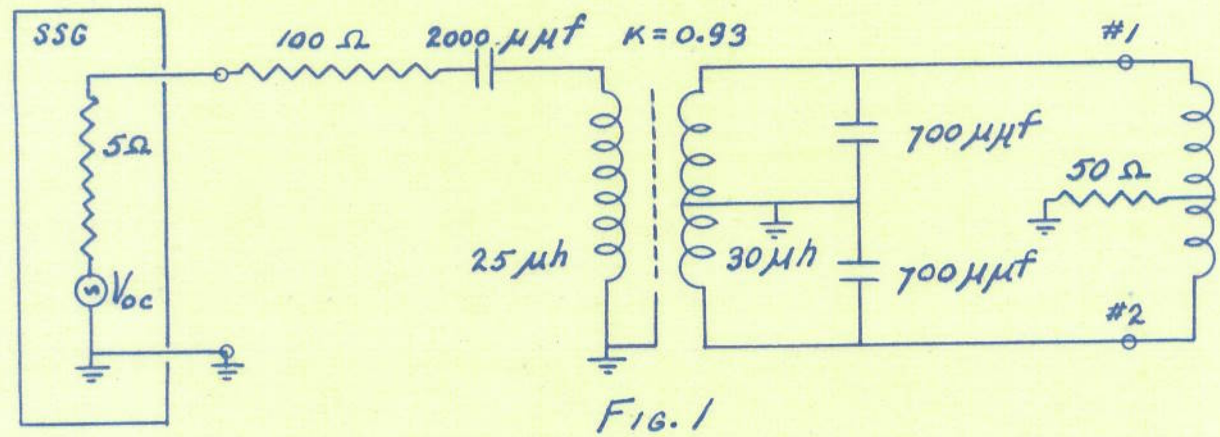


Fig. 1

N

Transformer 28 – 30 mcs (#2)

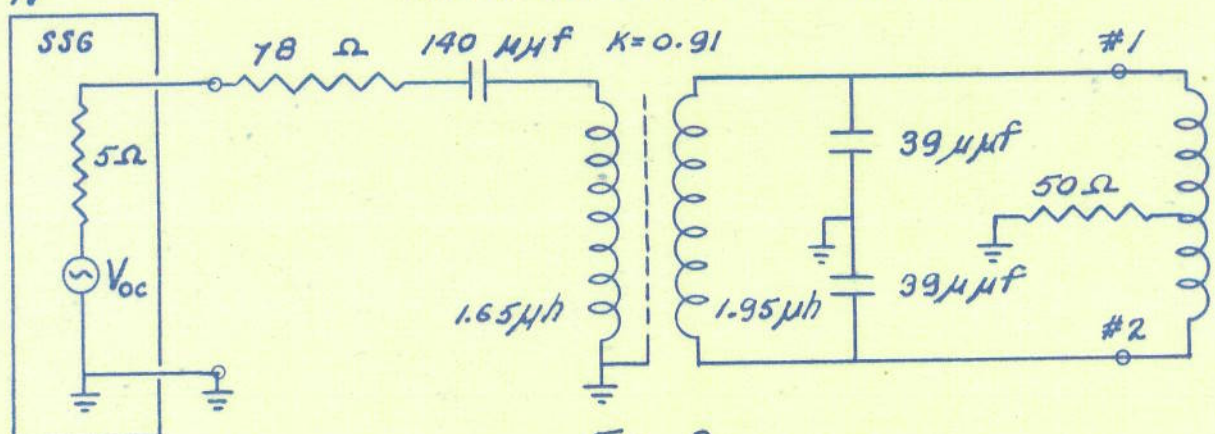
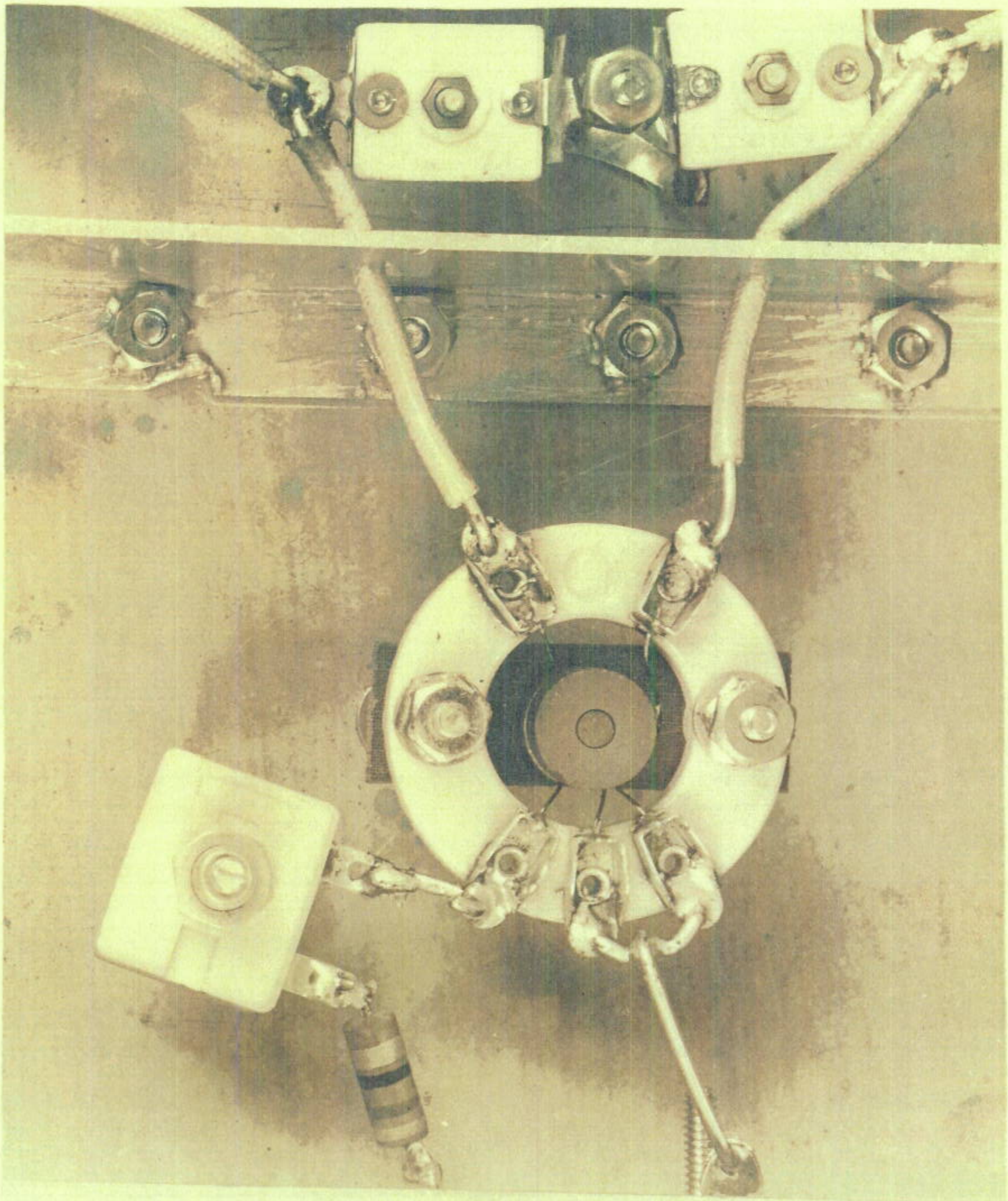


Fig. 2

Plate 3



BOTTOM VIEW OF HIGH FREQUENCY TRANSFORMER #2

Distribution:

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