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NAVAL RESEARCH LABORATORY REPORT

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TEST OF THE RE-SUBMITTED PRELIMINARY MODEL LD-1 COMBINED HETERODYNE FREQUENCY METER AND CRYSTAL CONTROLLED CALIBRATOR

By
R. B. Owens

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NAVY DEPARTMENT
OFFICE OF NAVAL RESEARCH
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NAVY DEPARTMENT

BUREAU OF ENGINEERING

Report on

Test of the Re-submitted Preliminary Model LD-1

Combined Heterodyne Frequency Meter

and Crystal Controlled Calibrator

Range 100 - 5000 kcs. for A.C. Operation

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D. C.

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Authorization: BuEng let. NOs-32278(9-21-W8) of 25 September 1933.

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Prepared by: _____
R. B. Owens, Assoc.Radio Engineer. (Chief of Section)

Reviewed by: _____
A. Hoyt Taylor, Physicist. Superintendent, Radio Div.

Approved by: _____
H. R. Greenlee, Captain, U.S.N. Director

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AUTHORIZATION

1. The test of this equipment was authorized in Bureau of Engineering letter NOs-32278(9-21-W8) of 25 September 1933.

PURPOSE

2. The purpose of the tests was to determine if the re-submitted preliminary Model LD-1 combined heterodyne frequency meter and crystal controlled calibrator complies with the governing specifications, RE 13A 401C, and is suitable for Naval use.

REFERENCES

3. (a) BuEng let. NOs-32278(9-21-W8) of 25 September 1933.
(b) Specifications RE 13A 401C.
(c) NRL Report No. RE-1006.
(d) BuEng let.NOs-32278(12-2-W8) of 6 December 1933 to INM, Schenectady.
(e) BuEng let.NOs-32278(12-2-W8) of 14 December 1933 to BuS&A.
(f) General Electric Company memorandum to Navy Department.

MATERIAL UNDER TEST

4. The re-submitted Model LD-1 frequency measuring equipment is the same unit as previously tested and reported on in ref.(c), except for the changes which are detailed in ref.(f) which were made to overcome the objections to the first model as mentioned in ref.(c).

METHOD OF TEST

5. The methods of test are the same as outlined in ref.(c), par.5.

RESULTS OF TESTS

6. Inasmuch as this equipment is being re-tested due to the failure of the first model to comply with certain requirements of specifications, ref.(b), only those paragraphs of the specifications will be commented on herein in which the results of the present tests differ from those given in ref.(c). Paragraphs in ref.(c) on which no comment appears in this report apply to the re-submitted model. The marginal numbers in this division of this report relate to the similarly numbered paragraphs in specifications, ref.(b).

2-5 and 3-13. In an ambient temperature of 2°C, the heterodyne cabinet thermometer registered not lower than 42°C, while the crystal temperature was the same as in an ambient temperature of 25°C.

In an ambient temperature of 22 to 25°C, the temperature control of both the crystal and heterodyne compartments was satisfactory with the crystal thermometer indicating 50.15 ± .1°C and the cabinet thermometer

registering 47 ± 1°C, provided the auxiliary cabinet heater was kept on continuously. When the auxiliary heater is left off, the crystal temperature varies from 50.15 to 51.0°C, with the crystal heater continuously off because the operation of the main cabinet heater alone (as coupled to its thermostat) permits the uppermost part of the cabinet in which the crystal compartment is located to reach a higher temperature than the crystal operating temperature. The temperature of this portion of the cabinet near the top of the crystal box was measured to be from 51 to 52°C when the cabinet thermometer (mounted several inches lower) indicated a temperature of 48°C and the crystal thermometer registered about 50.5°C. The operation of the crystal temperature control system thus appears to depend on the operation of the cabinet thermostat as affected by the auxiliary heater element or elements.

No cyclic variation in heterodyne frequency with heater operation was observed.

2-15. The action of the crystal when the equipment is inclined up to 45° in any direction is quite satisfactory. The frequency change with a tilt of 10° in any direction was not more than about .0002%. The maximum change noted up to 45° was .0012%.

The crystal did not fail to oscillate during these tests.

The heterodyne oscillator can be inclined in any direction up to 45° without a change in frequency as great as 0.002% and up to 20° with not more than 0.001% change in frequency.

3-18. No spurious oscillation now occurs on coil N.

3-29. The form of calibration is the same as described in ref.(c), par.3-29, except that additional calibration points are given as suggested in par.4-13 of ref.(c) and as stated in par.14 of ref.(f). It is considered satisfactory and provision for mounting on the tube door the case containing the data in scroll form is desirable.

Several errors were noted on the calibration submitted: 198 kcs is omitted and 196 is recorded twice; on coil J the value of "Kc per div." at 760 kcs should be .1022 instead of .0998; and on coil R at 4540 it should be .509 instead of .536; the setting on coil R for 4460 kcs should be 978 and not 987. The calibration data of all the coils was not checked for errors.

4-1. The overlap between coils has been very much improved and is satisfactory in the modified model except between coils K and L and between coils N and O. A setting of 2325 on K corresponds to 155 on L while a setting of 2349 on N gives the same frequency as occurs at 106 on O. The possible error involved in using the extreme ends of the condenser scale is indicated by noting that on coil K in the measurement of the frequency of 1135 kcs by the use of the"Kc per div."given on the calibration chart the measured frequency is 1134.6 instead of 1135.0. The error here is -.035%.

4-3. The measured frequency drift of the heterodyne oscillator during the "warming up" of the tubes follows:

Mins. after tubes on	Frequency Drift 120 kcs Observed	120 kcs Spec.	800 kcs Observed	800 kcs Spec.	4500 kcs Observed	4500 kcs Spec.
5-10	.002	.014	.0005	.0025	.002	.0021
10-15	.002	.0067	.0002	.0023	.003	.002
15-20	.001	.0017	.0005	.0015	.0015	.0015
20-25	.0008	.0008	.0002	.0009	.001	.0005

It will be observed that the drift is quite small. In fact the change in frequency at 120 and 800 kcs due to the voltage change caused by the off and on operation of the cabinet heater is greater than the drift in a 10 minute period during these tests.

At 120 kcs this frequency change is about four cycles (.003%) and at 800 kcs it is about six cycles (.0008%). At 4500 kcs the voltage change incident to heater operation causes a frequency change of 10 to 50 cycles. The voltage change with heater operation is about 1.5 volts, with both the main and auxiliary heaters on.

4-8. The audio output on multiples of 100 kcs is not less than 0.05 milliwatts at frequencies between 350 and 1100 cycles up to 4600 kcs. Between 4700 and 5000 kcs the output is of this value from 450 to 1100 cycles, but less between 350 and 450 cycles. At 5000 kcs, the output at 350 cycles is about 0.03 mw. with maximum gain and coupling, and with the harmonic control switch to the 5000 - 25000 kc position.

The audio output on all multiples of 20 kcs up to 3000 kcs is not less than 0.05 mws.

The audio output of this equipment is quite satisfactory. It may be added that the frequency of the audio frequency oscillator incorporated in the unit for matched tone settings is about 580 cycles.

4-13. It is now possible to quickly adjust the frequency meter to any frequency in the band 100 to 5000 kcs with an accuracy of 0.005% as required, provided the kilocycles per division values are accurately given and the overlap is sufficient so the condenser range does not have to be used below about 200 or above about 2250 divisions. The addition of calibration points as mentioned in par.14 of ref.(f), together with the reduction in back lash, makes the attainment of this degree of accuracy possible under the conditions just stated. Back lash in this model is never greater than 0.3 divisions.

To achieve the accuracy of 0.005% the value of kilocycles per division must be given to a higher degree of accuracy than was observed at some points on the calibration chart. For example, on coil J, beginning at 733.3 kcs, the "kc per div" values as given on the chart, and as determined at this Laboratory (locating zero beat by the use of the A F oscillator) for a few settings are given below together with values read from a smooth plotted curve of the condenser divisions plotted against these values.

	Kilocycles per Division		
Freq.(kcs)	G.E.	NRL	Read from Smooth Plotted Curve
733.3	.1018	.1020	.1019
740	.1012 a	.1026	.1021
746.6	.1035 b	.1018	.1021
753.3	.1018	.1020	.1021
760	(.1022) d .0998 c	.1024	.1019
766.6	.1018	.1012	.1015
773.3	.1003	.1004	.1009

NOTES: a is low and b is high due to setting at 746.6 kcs being about 1 division too high. c is error and d is correct value computed from data in chart.

As indicated in note a, a small error in setting or reading the dials may introduce a considerable error in the value of kilocycles per division and, therefore, in frequency measurement. If the frequency for 750 kcs should be computed using .1035 as the kilocycles per division, the error would be about +0.007%, whereas using .1021 the error would not be more than 0.001%.

The settings on which the values in the NRL column are based were taken with considerable care, the dial being turned clockwise throughout, and the scale read to tenths of divisions.

Errors in the value of kilocycles per division due to small inaccuracies in the dial readings can be eliminated by plotting the values as mentioned above and reading the values to be used from the curve, as illustrated in the last column of the table.

4-18. The audio oscillator has a frequency of about 580 cycles.

4-19. No binding has developed between the main and auxiliary dials. See pars.3 and 4 of ref.(f). In place of the circular transparent disc carrying the reference line for the dials, a u-shaped metal bracket is used to mount a small piece of the same material with the line on it. The only objection to this design is that the arms of the u-shaped bracket cover the numbers on the left dial at certain settings so that neither the one below or above the reference line can be seen without rotating the dial somewhat. For example, if the dial is set at around 1250 divisions both the 10 and the 15 on the hundreds dial are covered.

4-23. The crystal frequency is normally well within 0.002% of 100 kcs, but on perhaps 5 occasions during operation over 10 days, the crystal shifted to a different frequency which was accompanied by an increase in crystal oscillator plate current from 4 to 5 ma. If the equipment were shaken or jarred, normal crystal oscillation would be restored. The

presence of this condition could be noted by the rough noise when the multivibrator was operating.

4-28. The crystal frequency adjusting condenser is sealed after being set by the manufacturer. See par.11 of ref.(f).

5-6 and 5-7. In the power unit as received, the link on the relay potentiometer (symbol 213, see Instruction Book, p.3) was in the D.C. position, but was shifted to the AC position for use on the AC line. In this position the relay "chattered" at normal line voltage. When the link was replaced on the DC position, operation of the main heater relay was satisfactory.

8-1 to 8-5. The instruction book with the re-submitted model is practically the same as previously reviewed. An "index" has been inserted in the front. Ref.(f) states in par.18 that the instruction book will be brought up to date to cover changes made in the equipment and comments made in ref.(c).

The following additional comments are made on this instruction book:

(1) In line with the "matched tone" explanation on page 7 of the book, it is believed that on page 18 in pars.3 and 5 the words "zero beat with the audio oscillator" should read "a matched tone with the audio oscillator". The use of "zero beat" elsewhere on this page properly indicates the point of no audible beat between two practically identical heterodyning frequencies.

(2) Referring to pars. C-1-c and C-2-c on pages 18 and 20, it is not clear why step c (obtaining zero beat for point next below and next above the frequency to be measured) should be taken or why, if taken, it should precede step d (checking and adjusting calibration) since these points will probably not be the same after adjusting the compensator and since the lower point which alone is used is retaken in step e.

(3) Since the values of kilocycles per division given on the calibration chart should be more accurate than would likely be determined by the operator at the time of making a frequency measurement it does not appear that measurements made as directed in sections C-2 and C-3, pages 19 and 20 should be more accurate than as directed in C-1, page 18. Further, interpolation should always be made over the shortest interval. Therefore, pars.k and l at the top of page 19, and the first paragraphs of sections C-2 and C-3 should be properly modified or struck out.

(4) It is believed a shorter method of obtaining the setting for a desired frequency than that given in section D, page 20, is available by using the value of kilocycles per division on the chart. The following directions are suggested in place of those given in section D:

(a) From the calibration chart note the frequency (f_1) next below the desired frequency (f_o) and also the approximate setting.

(b) With the MV switch on 20 kcs, check and correct the calibration.

(c) Locate and set the dial at exact zero beat for f_1 (approximate setting noted in (a) above). This is S_1.

(d) Take the difference between f_o and f_1.

(e) Divide this value by the kilocycles per division opposite f_1 on the chart. Add this value to S_1 as determined in (c) above. This is the setting for the desired frequency f_o. Expressed in the form of an equation -

$$S_x = S_1 + \frac{f_o - f_1}{\text{kcs per div.}}$$

Par. (e) on page 21 is inaccurate as given.

(5) With respect to par.F-8, page 22, it is suggested that the word "recorded" in line 6 be replaced by the word "actual" and that the word "actual" in line 7 be omitted. The latter part of the sentence will then read "therefore, the actual frequency will be five times the measured frequency". As previously stated the back-lash is not more than 0.3 divisions at any point which is only 1/10th the maximum previously noted.

9-1. The re-submitted equipment complies with the requirements of the specifications, ref.(b), in all respects except that the overlap is insufficient in two instances and that the audio output at 350 cycles is slightly low over a very limited portion of the range. However, as previously stated, the audio output is considered quite sufficient for service use.

RECOMMENDATIONS

7. All the recommendations mentioned in ref.(c) are incorporated in the present unit. The following additional recommendations are made.

(a) With respect to overlaps, the used portion of the condenser range should be as little as possible below 200 and as little as possible above 2250 divisions. (See 4-1 herein.)

(b) If the auxiliary heater must be kept on for proper crystal temperature control the instruction book should so direct. (See 2-5.)

(c) The kilocycles per division values must be more nearly accurate. (See comment on par.4-13.)

(d) The dial reference line bracket should be changed to prevent its covering two sets of dial frequencies on the left dial at once or additional figures should be engraved on this dial. (See 4-19.)

(e) Crystals should be carefully tested for "doubles". (See 4-23.)

(f) The main heater relay must operate with the link on the relay potentiometer on the AC position when the AC supply is used. (See comment under 5-6 and 5-7.)

(g) Calibration data should be carefully proofread to eliminate errors. (See 3-29 and 4-13.)

(h) The clamp on the crystal thermo-regulator should be moved so as not to cover both contact rings, to prevent the possibility of shorting the thermostat in case the strip of felt should be become unglued from the clamp.

(i) Brief instructions for setting the frequency meter to a desired frequency should be added to the chart, if feasible.

CONCLUSIONS

8. With the recommendations for minor changes mentioned in the preceding paragraph carried out, the re-submitted Model LD-1 frequency measuring equipment complies with all provisions of the governing specifications so far as could be determined, and is considered quite suitable for Naval use for the purposes intended.