17 May 1934

Report No. R-1053
BuEng.Prob.R5-7

NAVY DEPARTMENT

BUREAU OF ENGINEERING

REPORT ON

Test of Hammarlund Comet "Pro" Receiver

Serial No. 7448

Range 1200 - 20000 Kcs.

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D.C.

Number of Pages: Text - 11 Plates - 17.

Authorization: Bu.Eng. let. S67/46(9-16-W8) of 19 Sept. 1933.

Dates of Test: 1 December 1933 to 9 January 1934.

Prepared by:
S. A. Greenleaf, Assistant Radio Engineer.

Reviewed by:
T.McL. Davis
Head, Receiver Section

A. Hoyt Taylor,
Supt. Radio Division.

Approved by:
H. R. Greenlee, Captain, USNavy

Distribution:
BuEng.(5)

mbe

TABLE OF CONTENTS

SUBJECT PAGE

1. AUTHORIZATION.. 1

2. PURPOSE OF TESTS.. 1

3. REFERENCES.. 1

4. EQUIPMENT UNDER TEST.. 1

5. METHOD OF CONDUCTING TESTS.................................... 3

6. RESULT OF TESTS... 4

7. CONCLUSIONS... 10

Appendices

Sensitivity, CW input, Crystal filter out...........PLATE 1

Sensitivity, CW input, Crystal filter in............PLATE 2

Sensitivity, MCW input, Crystal filter out..........PLATE 3

Selectivity, MCW input..............................PLATES 4 to 8 incl.

Selectivity, CW input, Crystal filter in............PLATES 9 to 11 incl.

Audio Characteristics...............................PLATE 12

Resonant Overload - CW input........................PLATE 13

Resonant Overload - MCW input.......................PLATE 14

Maximum Noise - CW oscillator on....................PLATE 15

Maximum Noise - CW oscillator off...................PLATE 16

Schematic diagram of Circuit........................PLATE 17

AUTHORIZATION

1. The test of this equipment was authorized in Bureau of Engineering letter S67/46(9-16-W8) of 19 September, 1933, under Problem R5-7.

PURPOSE OF TESTS

2. The examination and test of Hammarlund Comet "Pro" receiver Serial No. 7448, to determine its performance and characteristics. The Bureau of Engineering designated, in ref.(a), that this receiver be subjected to tests similar to those to which the DeForest Model RRH-11 receiver was subjected as reported by ref. (b).

REFERENCES

3. (a) BuEng. let. S67/46(9-16-W8) of 19 Sept. 1933.
   (b) NRL Report RE-271 dated 27 July 1933, forwarded by NRL let. S67/46 of 28 July 1933.

EQUIPMENT UNDER TEST

4. The subject receiver, manufactured by the Hammarlund Mfg. Co., Inc. New York City, is of the double detection or superheterodyne type, employing eight tubes, and is A.C. operated from 110 volts, 60 cycles supply line with means for converting to suitable filament and plate voltages contained within the receiver. The frequency range is from 1200 to 20,000 Kcs. covered by the use of four sets of two each plug-in coils. These coils are replaced by raising a cover on top of the receiver, and removing two shield cans.

5. Tuning is accomplished by two vernier dials which individually control the grid circuit of the first detector and the grid circuit of the first oscillator. These are termed tank condensers. Single dial tuning may be further accomplished over a limited range by the use of a third dial, termed the main dial, which gang controls condensers in parallel with both tank condensers. By setting the main dial at 50 and resonating the two tank condensers, tuning over the entire range of the main dial which is 0 to 100 may be accomplished without further adjustment of the tank condensers, giving a band above and below the resonant setting of the tank condensers, the width of which varies from approximately 225 Kcs. at the lowest frequencies to 1500 Kcs. at the highest frequencies. This is known as the 'Band Spread' feature.

6. Other controls on the panel consist of a switch for turning the second oscillator on or off, a volume control dial which controls the bias voltage of the intermediate amplifier grids, and a filament switch, the rotation of this switch dial also operating a tone control which consists of a variable shunt around the primary of the output transformer to attenuate the higher audio frequencies for the purpose of reducing the noise under certain conditions. There is also an 'on' and 'off' switch for the crystal filter in the first intermediate stage, and a dial for the phasing condenser in the filter circuit.

7. A jack for the 'phones' output is on the front panel, and the main dial is illuminated with a pilot light.

8. The receiver case is 9.5 inches high, 20.75 inches wide, and 12.25 inches deep, with 3/8 inch additional ventilator projections at the back and at both ends. The receiver complete with tubes weighs 45 lbs.

9. The input circuit consists of a coil, with a terminal for each end of the coil, for use with transmission line or dipole antenna. There is a third ground terminal for use with ordinary antenna ground system in which case a jumper is used from one of the coil terminals. This coil is electromagnetically coupled to the tuned grid circuit of the first detector tube. There is also coupled to the first detector grid, through a 0.6 m.m.f. condenser, the output circuit of an electron coupled oscillator to heterodyne the signal frequency for setting up an intermediate frequency of 465 Kcs. Two stages of intermediate frequency amplification follow, a quartz crystal filter being placed between the first detector plate circuit and the grid circuit of the first i-f tube. This filter may be cut in or out as desired and a description of the circuit and its action will be given in the section relating to selectivity tests. The last intermediate coupling transformer is Litz wound, with both the plate and grid circuits tuned by air dielectric variable condensers. The secondary of the last i-f transformer is directly coupled to the grid of the second detector. To the primary of this transformer is coupled the output circuit of a second electron coupled oscillator for heterodyning the intermediate frequency for CW reception.

10. The plate circuit of the second detector is resistance-capacity coupled to the grid of the audio frequency amplifier tube. A two stage filter consisting of three 250 m.m.f. condensers and two 85 millihenry chokes is incorporated in the plate circuit of the second detector to suppress the fundamental and harmonics of the i-f component in this circuit and eliminate undesirable feed-back.

11. In the plate circuit of the audio amplifier tube is an output transformer, across the secondary of which are the loud speaker output terminals with an approximate output impedance of 4,000 ohms. A tap on the secondary is connected through a resistor to the jack on the front panel for head-phone reception at reduced volume.

12. Pentode tubes, commercial type '57, are used for both the first and second detectors, and pentodes, commercial type '58, for the first and second oscillators; also in the two intermediate stages.

13. A power amplifier pentode, commercial type 2A5, is used in the audio stage. The biased detector method is used for each detector, and both oscillators use electron coupling between the inner and outer anodes.

14. Grid bias voltages are obtained by the use of resistors in the cathode circuits. A commercial type '80 full wave rectifier tube is used to obtain plate supply with a voltage divider to provide the necessary voltages. Transformers are included for the plate and filament supply of the rectifier tube, also a transformer to supply heater voltage for all other tubes. This equipment is all contained in the receiver.

METHOD OF CONDUCTING TESTS

15. A Model LC-1 standard signal generator was used to supply all input test r-f voltages; an audio oscillator, General Radio type 513-B, to supply audio frequency voltages; and an output meter, General Radio type 483-C, resistance 20,000 ohms, to measure outputs. For the purpose of this test, the following definitions are applicable:

Standard Output is 5 milliwatts, or 10 volts across 20,000 ohms.

Sensitivity is shown as the microvolts input through 300 ohms resistance for standard output, with gain adjustment for a noise level of 0.5 volt across 20,000 ohms.

Selectivity is shown as the ratio of input for standard output at percentages of frequency above or below resonant frequency to the input for standard output at resonant frequency.

Primary image frequency is defined as any input frequency, other than that for which the signal frequency circuits are resonated for normal operation, whose fundamental frequency combined with the fundamental frequency of the first oscillator, will produce the fundamental frequency for which the i-f stages are resonated. No discrimination is made between the two closely related frequencies producing a-f beats, on opposite sides of zero beat, one of which must be considered an image frequency.

Secondary image frequencies are defined as those other frequencies which when combined with the fundamental frequency or harmonics of the first oscillator will produce a beat frequency to which the i-f system will respond. This may be a resultant frequency of which the i-f frequency is a harmonic, or other possible combinations.

Audio Characteristics are shown as the attenuation in decibels above and below a reference level which is taken as the voltage gain of the audio amplifier at 1,000 cycles.

16. All input test voltages are applied through 300 ohms resistance. The following tests were made:

- (a) Sensitivity, CW input, crystal filter out and in.
- (b) Sensitivity, MCW inout, crystal filter out.
- (c) Selectivity, MCW input, crystal filter out.
- (d) Selectivity, CW input, crystal filter in.
- (e) Audio amplifier characteristics.
- (f) Resonant overload.
- (g) Maximum noise level.
- (h) Primary and secondary image response.
- (i) Response of i-f system to frequencies other than the fundamental intermediate frequency.
- (j) Interaction between receivers.
- (k) Effect of change in line voltage.

RESULT OF TESTS

17. (a) Sensitivity, with CW input, and gain adjustment for 0.5 volt noise, is shown with crystal filter out on Plate 1 and with crystal filter in on Plate 2.

(b) Sensitivity, with CW input modulated 30% at 1,000 cycles, and gain adjustment for 0.5 volt noise, is shown with crystal filter out on Plate 3.

(Note:- These measurements are taken across the 'phone' output terminals. By matching the impedance at the 'speaker' output terminals it is found that for a given input, the output is increased by 14 DB's.

(c) Selectivity, with CW input modulated 30% at 1,000 cycles, taken with CW oscillator off, with crystal filter out, and with gain adjustment for 0.5 volt noise is shown on Plates 4 to 7 inclusive. Selectivity, taken as above, is shown on a large scale at and near the peak of the curve for inputs to 10 times that at resonance on Plate 8.

The crystal filter circuit is placed between the detector plate and first i-f grid circuits both of which are tuned. The coupling both into and out of the filter circuit is through transformers. These transformers have been designed so as to suitably match impedances, it being assumed that the detector plate and i-f grid circuits are of high impedance, and that at the acceptance frequency of the bridge, its input and output will be of relatively low impedance.

The secondary of the input transformer has a grounded center tap, the two halves forming two legs of the bridge. The other two legs consist of the crystal and a so-called phasing capacitor. The primary of the bridge output transformer is coupled through a small capacitor from the common point between the crystal and the phasing capacitor to ground. Provision is made for shortcircuiting the crystal when not in use.

It can be assumed that for frequencies well away from resonance that the crystal and its holder act substantially as a capacitance, and that by proper adjustment of the phasing condenser the bridge could be so balanced that no voltage would exist across the primary of the bridge output transformer. It can further be assumed that if a voltage is applied at crystal resonance frequency, the crystal will act as a series resonant circuit of relatively large inductance, small capacitance and resistance, under which condition the bridge will be unbalanced and a voltage will exist across the bridge output transformer. It is also well known that the reactance of a series circuit off of resonance may either be inductive or capacitive depending upon the side of resonance considered.

This principle is utilized by making the phasing condenser variable, thus permitting its capacitive reactance to be varied to equal that existing in the crystal bridge arm at some frequency slightly below the series resonant frequency of the crystal itself. When the capacitive reactances of the two bridge arms (crystal and phasing condenser) are equal, there will be no current flow in the output transformer which is coupled to the junction of these two arms. This assumes that the losses of the two arms are negligible. This minimum response point appears to be the condition referred to in published articles on this type of circuit, as the "anti-resonant" point, and has been utilized in the subject receiver to give audio image suppression or so-called "single signal reception". In the subject receiver, it has been found that the "anti-resonant" (minimum response) point may be varied from zero beat (crystal series resonance) to around 1500 cycles lower in frequency. It has also been observed that another secondary acceptance point which appears to have sharpness comparable to the primary point exists at about 1% below the crystal resonance frequency. The response from this secondary acceptance point is shown on Plates 10 and 11 to be about 30 DB down from that of the primary. At 1% off receiver resonance, attenuation of this order might be expected from the receiver selectivity alone. The secondary acceptance points have been referred to as "crystal humps". The dimensions of the particular "X" cut crystal used in the subject receiver indicate by calculation approximate resonant frequencies of 463 and 185 Kcs. for thickness and width respectively. The thickness frequency agrees rather closely with the primary response of 472 Kcs. but the width oscillation does not appear to bear any relation to the so-called additional "crystal hump". Complete analysis of possibilities of performance of crystal filters would be an undertaking of considerable magnitude and has not been undertaken in connection with this investigation.

(d) Selectivity, with the crystal filter in, and taken with a CW input, is shown for three different settings of the phasing condenser, the resonant frequency being 1568 Kcs.

At crystal series resonance, the sensitivity is not affected by the variation of the phasing condenser.

Plate 9 shows the selectivity with the phasing condenser set at 0, the curve being symmetrical except for the point of no response at zero beat and a secondary resonance response at a frequency slightly under 0.4% higher than resonant input frequency. Shifting of the phasing condenser does not affect the frequency at which this secondary resonance response appears. Plate 10 shows the selectivity with the phasing condenser set at 10, which is the maximum capacitance setting. With this condenser setting, the point of minimum response is shown to fall between resonance and zero beat.

Plate 11 shows the selectivity with the phasing condenser adjusted about half scale, or between 5 and 6, and in this curve the minimum response point (a) falls on the opposite side of zero beat from resonance or near the audio image frequency.

A second point of minimum response (b) has been found apparently bearing the same relation to the secondary response point (c) as the first point of minimum response (a) bears to the primary response point (d).

(e) The audio amplifier characteristics are shown on Plate 12, in DB's above and below 1,000 cycles as a reference level. This is taken with audio frequency applied to the plate circuit of the second detector through 5,000 ohms resistance, and ahead of the two stage filter system incorporated in this circuit.

(f) Resonant overload curves taken at 7700 Kcs., with CW input and CW modulated 30% at 1,000 cycles input, are shown on Plates 13 and 14.

(g) Maximum noise level, with CW oscillator on and crystal filter out and in, is shown on Plate 15. Maximum noise level, with CW oscillator off, and crystal filter out, is shown on Plate 16.

(h) Primary image response is noted at input frequencies equal to the combined frequency of the first oscillator and the intermediate frequency, but with an attenuation of 40 DB's from the response at resonant input frequency.

Secondary image response is noted: (a) at input frequencies of which the resonant frequency is a harmonic; (b) input frequencies of which the primary image frequency is a harmonic; (c) input frequencies which when combined with the frequency of the first oscillator produce a frequency of which the intermediate frequency is a harmonic; (d) input frequencies of which the intermediate frequency is a harmonic; and (e) an input frequency equalling the intermediate frequency.

It must be considered, however, that where the response is due to a harmonic of the signal generator frequency that this is probably more a characteristic of the signal generator output. It is also believed that most present day transmitters emit harmonics to a certain extent. The following tabulation shows the response at frequencies other than that for which the receiver is resonated. For this test, the receiver was resonated at 2,000 Kcs. which made the first oscillator frequency 2,472 Kcs. (the intermediate frequency being 472 Kcs. as checked with the calibration of the signal generator used). The gain was adjusted for 0.5 volts noise.

Frequency Kcs.	Microvolts input for standard output
26.2	500,000
26.6	415,000
27.2	228,000
27.5	420,000
28	233,000
28.3	127,000
28.7	475,000
29.1	150,000
29.5	100,000
29.7	165,000
30	437,000
30.4	92,000
31	130,000
31.8	278,000
31.9	140,000
32.4	140,000
32.9	320,000
33.5	143,000

Frequency Kcs	Microvolts input for standard output
118	4,640
126	3,200
134.4	2,100
144	2,200
157	28,200
166	10,500
182	10,500
184	245,000
196	245,000
200	10,000
210	180,000
222	3,100
226	130,000
236	41,000
245	125,000
250	3,000
267	110,000
285	7,000
294	62,000
327	45,000
333	1,100
368	48,000
400	24,500
472	1,170
500	37,000
666	7,500
981	282,000
*1000	6,800
*1000	90,000
1472	113,000
2236	122,000
2708	346,000
2944	1,100

From the above tabulation, it will be noted that the following are examples in kilocycles of the different forms of secondary image response as designated by letter

(a) 1000, 666, 500, 400 etc.
(b) 1472, 981, 736, 588, etc.
(c) 2236, 2708.
(d) 236, 157, 118, etc.
(e) 472.

*In explanation of the difference between the two readings taken with a 1000 Kcs. input, the first was taken at the high frequency end of a signal general coil and the second at the low frequency end of the next coil. The wide difference in values is an indication of the different percentages of harmonic content for the two L/C ratios used in the signal generators.

(i) By applying a CW modulated 30% at 1000 cycles signal to the grid of the first detector tube, with the first oscillator inoperative, the following response to frequencies by the intermediate system was noted.

Frequency	Microvolts input for standard output
472	17
236	510
157	420
118	210
94.5	445
78.6	1300
67.4	680

As the above frequencies all bear harmonic relationship to the fundamental intermediate frequency (472 Kcs.) for which the intermediate amplifier stages are tuned, this data gives an idea of the harmonic content of the signal generator output and is not presented as an indication of receiver performance.

(j) In testing for interaction between receivers, the subject receiver was connected to the same antenna with a National FBX receiver. The subject receiver was resonated at 2,000 Kcs. which made the first oscillator frequency 2472 Kcs. and the second oscillator 472 Kcs.

Response on the National FBX was noted as follows, output in volts across 20,000 ohms.

Kcs.	Volts output
2472	130
4944	45
7416	90
9888	26
12360	18
14832	2
17304	3

The above frequencies are the fundamental of the 1st oscillator and its harmonics. An output of approximately 2 volts was also obtained on several harmonics of the second oscillator, the first oscillator being shut off in each case in order to identify the signals as coming from the second oscillator alone.

(k) To determine the effect of change in line voltage the voltage was varied from 90 to 120 and change in audio output frequency noted, based on receiver adjustment with voltage at 110 as tabulated below:

Carrier, 2000 Kcs.

Line volts	Frequency after 30 sec.	Frequency after 3 min.
110	1000 cycles	
115	950	860
120	900	850
105	1050	1050
100	1100	1100
95	1180	1220
90	1300	1350

Carrier, 16000 Kcs.

Line volts	Frequency after 30 sec.	Frequency after 3 min.
110	1000	
115	900	800
120	800	600
105	900	1050
100	1050	1200
95	1200	1500
90	1400	2000

CONCLUSIONS

18. The usable sensitivity of this receiver is very good, the input required for standard output of 5 milliwatts at the 'phone output terminals averaging as follows:

For CW signals, crystal filter out, 18.1 microvolts, varying from 8.7 to 50 microvolts.

For CW signals, crystal filter in, 5.5 microvolts, varying from 2.2 to 23.3 microvolts.

For MCW signals, 9.7 microvolts, varying from 5.5 to 19.5 microvolts.

These measurements are based on a noise output of not to exceed .0125 milliwatts. Sensitivity with the crystal filter in is improved by reason of the higher gain adjustment permitted to keep within the required noise level.

The selectivity is very good, showing an attenuation of 60 DB's at 1.25% off resonance at the lowest frequency, and an attenuation of 60 DB's at 0.1% off resonance at the highest frequency.

By the use of the crystal filter, or so-called 'single signal' the selectivity is enhanced, permitting the elimination of interference at a particular frequency near to resonant frequency.

The near resonant selectivity is somewhat offset by the acceptance of various image frequencies. Although this would not be particularly objectionable when the receiver is used at a few miles from a transmitting station, it would be of sufficient importance as to prevent consideration of its use aboard naval vessels.

Resonant overload curves show that the receiver is capable of satisfactorily handling outputs up to 30 milliwatts at the 'phone terminals and 750 milliwatts at the speaker terminals.

There is considerable interaction between receivers from the first oscillator frequency and its harmonics, and slight interaction from the second oscillator frequency. This condition would prevent r recommendation of its use in the Naval Service where more than one receiver may be employed either on the same antenna or with closely coupled separate antennas. When the two tank condensers are set for a given frequency, single dial tuning is accomplished in the usual manner over a limited range of frequencies adjacent to the frequency for which tank condensers are set. This band spread feature is convenient and practical in this particular unit where the ganging of but two condensers is required. Its practicability is questionable if used in receivers where several condensers are essential for greater preselectivity, especially if actual receiving calibration is required throughout the range. Stable operation is obtained throughout the entire frequency range, and the volume control operates in a manner to give positive control of the output with respect to reducing the signal and noise at their existing ratios. This must, however, be qualified for the reason that with the crystal filter in, the tuning to resonance is so extremely critical that it is very difficult to set the tuning condenser at this point even with the greatest care in handling, and the usefulness of the crystal filter under service conditions is questionable due to the difficulty in obtaining maximum efficiency of the circuit. Its use would be wholly impracticable except with signals from transmitters having excellent frequency regulation.