RADIO CORPORATION PTY. LTD.
DIVISION OF ELECTRONIC INDUSTRIES LTD.
126-130 GRANT STREET, SOUTH MELBOURNE, S.C.4.

# TECHNICAL BULLETIN

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SUBJECT–Hazeltine Routine Measurements on Radio Receivers (1939).

We wish to draw your attention to the recently distributed "ASTOR" Service Manual in which a section entitled 'Technical Journals (J)' is included. Under this section we plan to issue information of a technical nature as distinct from the details issued and filed under 'Service-General (G) and referring to the servicing of specific models. By so doing, we hope to provide a means of establishing a broader understanding of the "ASTOR" tradition among our many friends who handle and service "ASTOR" Receivers.

The name of "ASTOR" has endured for more than twenty years and the original policy of pioneering and progressive enterprise in receiver design remains unchanged to-day. It will be readily understood that the success of such a policy depends upon the soundness of the underlying basic principles which are applied to the production of new receiver design. "ASTOR" receivers are designed according to a system known as the 'Hazeltine Principles of Design' in conjunction with the published Hazeltine Routine Measurements on Radio Receivers (1939).

We wish to acknowledge the courtesy of Hazeltine Electronics Corporation America and Neutrodyne Pty. Ltd. in granting us permission to issue the routine measurements as a technical journal for the exclusive use of our "ASTOR" service men. We hope that the wide spread use of this standard method of measurement will provide a common basis upon which to build up a technical service in our Service Manual.

SUBJECT-HAZELTINE ROUTINE MEASUREMENTS ON RADIO RECEIVERS (1939)

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## INTRODUCTION.

The Hazeltine Electronics Corporation has developed a routine measuring procedure, which experience has indicated includes substantially all the measurements necessary to give complete information as to the performance of a radio receiver The measurements have been selected so that many incidental characteristics of the receiver under test may be computed. The procedures outlined in this report by no means exhaust the variations necessitated by a consideration of the special requirements of particular circuit designs, but suffice for the great majority of receivers. It is believed that the information furnished herewith will be of value in the interpretation of our reports.

The essential equipment used in making these tests is described briefly.

## EQUIPMENT.

Standard Signal Generator.—A Block diagram showing the connections of the signal generator, the receiver, and the other equipment used in the overall measurements is given in Figure 1.

The standard signal generator is capable of delivering a signal of at least one r-m-s volt over a frequency of 85 kc. to 24 Mc. An attenuator is provided for reducing the output continuously to about 0.1uv. A 400-cycle internal modulator is provided, and the percentage modulation can be varied by a tap switch between 0% and 50%.

Dummy Antenna.—The signal from a standard signal generator is introduced into the antenna circuit cf the receiver under test through a dummy antenna. This dummy antenna is the all-wave I.R.E. standard, comprising a series connection of 200uuf, 400uuf and 400Ω, with 20uh shunting the 400uuf and 400Ω. The characteristics of this dummy antenna are given in page 20 "Standards on Radio Receivers 1938" (I.R.E., U.S.A.).

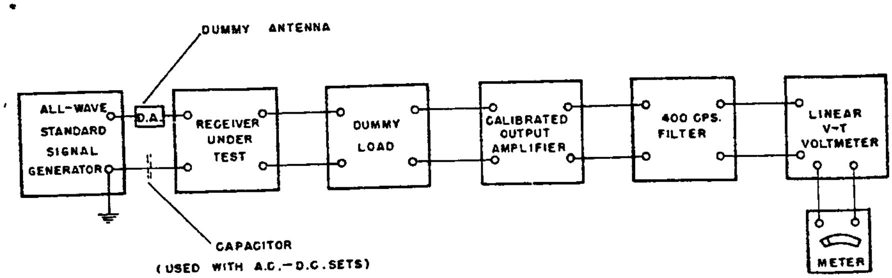


**FIGURE I.**
ARRANGEMENT OF EQUIPMENT FOR OVERALL MEASUREMENTS.

Standard Dummy Load.—When making the usual output measurements on a receiver having an output transformer, a dummy load is inserted in place of the voice coil of the loud speaker. The resistance used for the dummy load is equal to the d-c resistance of the voice coil. In the case of receivers using loud speakers of the magnetic-armature type, the speaker is removed and an iron-core coil substituted; a dummy load of the resistance recommended for the output tube or tubes is shunted across the choke. A.R.T.S. Bulletin 79 describes the voice coil dummy load equipment.

It is well to note that the receiver performance measurements made with a dummy load resistor do not include any effects due to the loud speaker itself.

Output Amplifier.—A calibrated amplifier unit is connected between the dummy load and the 400-cycle filter, primarily to widen the voltage range over which accurate measurements can be taken, and also to provide a high-impedance source for feeding the 400-cycle filter unit. This amplifier is described in A.R.T.S. Bulletin 79.

400-Cycle Filter.—A sharply-tuned filter network, designed to remove noise from the output of sensitive receivers and still pass 400 cycles, is located ahead of the output meter. A switch is provided to take the filter out of circuit when desired. More detailed information about this filter is contained in A.R.T.S. Bulletin 52.

Output Meter.—The type of output meter generally used in this laboratory (also described in Bulletin 52) is a linear, peak-reading, tube voltmeter having a suitably damped microammeter as an indicating instrument. When used with the calibrated output amplifier unit mentioned above, a range of 0.03 volt to 100 volts can be measured.

Audio-Frequency Generator.—For overall electrical fidelity measurements, an r-f generator is modulated externally by a signal from a beat-frequency audio generator. The beat-frequency range is from 0 to 10,000 cycles. A zero-beat indicator is provided for initial adjustment.

Portable Tube Voltmeter.—For the measurement of voltages at frequencies from 50 cycles to about 25 Mc., a portable tube voltmeter has been developed in this laboratory. This equipment consists essentially of a small case housing the circuit elements and serving as a base from which rises a flexible "gooseneck" metal tube which supports the tube socket and vacuum tube and also acts as a shield for the wires from the socket to the case. A sensitive microammeter, suitably damped to facilitate observations, is connected externally. A battery box completes the equipment. This voltmeter is characterized by a low input capacity (6uuf), and by an input resistance high enough to cause no appreciable damping of the circuit across which it is connected. The gooseneck feature permits very short connections from the circuit under test to the vacuum tube of the voltmeter. The plate-current change of this voltmeter is proportional to the square of the corresponding grid-potential change, so that bandwidths at half-amplitude, for example, are measured at quarter deflection on the microammeter. A calibration curve of the microammeter readings for various signal voltages is provided with each instrument. This volt-meter is described in United States Patent No. 1,910,827 which was issued on May 23, 1933.

Another type of v-t voltmeter, of somewhat similar general design, is used where greater sensitivity is required and for frequencies up to about 150 Mc. This voltmeter uses an acorn tube.

Multi-Range Reactance Meter.—This instrument is designed to measure the reactance of coils and condensers, to measure tuned-circuit constants at operating frequencies, to determine the alignment errors of ganged circuits, and to facilitate the matching of coils, condensers, etc. It is used in routine measurements to determine the alignment of the antenna tuned circuit with respect to other signal-frequency circuits, and to measure the effect upon the antenna tuned circuit of various values of antenna capacity.

The reactance meter consists essentially of two tunable r-f oscillators which, in operation, are made to give an a-f beat which in turn is rectified; means are provided to indicate zero beat. One oscillator operates at the test frequency, and is called the "reference oscillator." The other oscillator, which is called the "beating oscillator," is provided with external terminals whereby the element under test may be connected across its tuned circuit. The test-frequency range of this instrument is from approximately 90 kc. to 25 Mc.

Equipment for Measuring Oscillator Alignment.—The measurement of alignment between the oscillator and tuned circuit and the signal-frequency tuned circuits in a superheterodyne receiver is facilitated by a dry cell type triode arranged in a circuit which employs the tube as a simple transformer-coupled audio amplifier. The audio transformer is tuned to approximately 400 cycles to give maximum response at the usual modulation frequency of standard signal generators. A pair of headphones is provided for listening to the modulation.

The unit is entirely contained in a portable metal box. The filament is heated by dry cells located within the box, and the plate supply is obtained from the receiver under test by connecting the unit in the +B lead from the i-f transformer in the plate circuit of the receiver modulator tube. A ground lead is provided to connect the meter chassis to the -B return of the receiver. A more complete description of this apparatus is contained in A.R.T.S. Bulletin 35.

## OVERALL MEASUREMENTS.

Conditions as to Receiver Alignment.—The overall sensitivity of the receiver is measured before disturbing the alignment existing when it was received from the manufacturer. Single-stage measurements are then made, and when they are completed the receiver is aligned in accordance with usual factory overall alignment procedure. Normally no overall measurements are made with the receiver aligned at each test frequency. Special procedure for alignment specified by the manufacturer is followed if the information is available, otherwise our engineers use their own judgment. In any case, the frequencies at which the oscillator is in exact alignment with the mean frequency of the signal-frequency circuits are indicated in the report.

Frequency Coverage.—The resonant frequency corresponding to the maximum and minimum capacities of the gang tuning condenser are recorded for each wave band.

Overall Selectivity.—The overall selectivity of the receiver is measured at 1,000 kc. The set-up for the sensitivity is used. The total widths of the selectivity curve corresponding to 1/2, 1/10, 1/100, 1/1000, and 1/10,000 of the resonant voltage peak are recorded in kilocycles as W2, W10, W100, W1,000, and W10,000. The signal input is increased as the signal generator is tuned off resonance so as to maintain a constant audio-frequency output.

This selectivity measurement is taken, although in some cases additional measurements are required to give complete information on the selectivity. For example, in the case of a receiver incorporating a double a-v-c system such a measurement will indicate a much sharper selectivity than is provided by the selectivity of the resonant circuits. This is true to some extent in any receiver which has less selectivity to the a-v-c detector than to the signal detector.

Equivalent Tweet Modulation.—The audible whistle or "tweet," observed when receiving a signal having a frequency close to twice the intermediate frequency, is measured at several values of signal input level and compared with the corresponding 400-cycle modulated signal by expressing the tweet in terms of the percentage modulation at 400-cycles required to give the same output voltage as the tweet.

Data of this type may indicate a high equivalent tweet modulation either at low or high signal inputs, or at low and high inputs. A high tweet modulation at low inputs indicates feedback of the second harmonic of the i.f. from the second detector, the last i-f stage, or the first a-f stage. This undesired signal is fed back through various stray couplings to the antenna circuit, where it beats with the incoming signal to produce a tweet. This type of tweet can often be reduced by improved filtering of the i-f and a-f leads, by improved shielding, relocation of wiring, etc.

Tweet modulation at high inputs results from the production of the second harmonic of the signal in the modulator, or sometimes in the r-f stage; this harmonic beats with the fundamental of the local oscillator to produce an i.f., which when the receiver is slightly detuned, beats audibly with the i.f. produced by the fundamental frequency of the signal. For example, with a 910-kc. signal and a set having an i.f. of 455 kc., if the set is slightly detuned to an oscillator frequency of 1364 kc., the second harmonic of the signal, 1820 kc., beats with the oscillator and produces 456 kc., while the normal action of the modulator produces 454 kc. A tweet of 2 kc. is therefore heard. This type of tweet is much more difficult to reduce than the tweet produced at low inputs, and cannot be entirely eliminated with present circuit arrangements.

The equivalent tweet modulation measurement is made with the regular set-up for overall measurements, except that the voice coil of the speaker is connected. The signal generator, with zero modulation, is tuned to approximately twice the i.f., and the signal introduced through the dummy antenna. The signal input level is set at 1 volt, and the 400-cycle filter disconnected; the receiver (not the signal generator) is detuned to produce a tweet of maximum intensity to the ear; the volume control is reduced so that the tweet voltage output at this point is well below the overload level; this voltage is recorded.

The 400-cycle filter is then connected, modulation is applied to the signal generator and adjusted to the level which gives the nearest approach to the output voltage measured for the tweet, and from the ratios of these output voltages the equivalent tweet modulation is computed. This procedure is then repeated for inputs of 100,000, 10,000, and 1,000 uv.

When measuring the tweet modulation at input levels of 100uv and less, the above procedure must be modified, as the noise tends to mask the tweet when no filter is used. Therefore the 400-cycle filter is connected at all times, and the frequency of the tweet carefully adjusted to give maximum output; then the receiver tuning is slightly changed to reduce the tweet frequency well below the 400-cycles and the modulation applied as before. The equivalent modulation of a tweet at 400-cycles is usually substantially less than that of a higher-frequency tweet, when the a.v.c. is in operation. However, these low-level tweet measurements are usually only important qualitatively, as indicative of the need for work on the set to eliminate the causes of the tweet. With a thoroughly shielded receiver of correct design the tweet is usually not measurable with inputs below 100uv.

The reason for detuning the receiver rather than the generator is that the rate of change of pitch of the tweet is different in the two cases and consequently the intensity to the ear for a given pitch is different because of greater or less a-v-c action. Since the measurement is intended to represent the "annoyance value" of the tweet in service, it should be taken under service conditions, viz., with fixed frequency input and variable receiver tuning.

Sensitivity Measurement Allowing for Noise.—Background noise in the output of a sensitive receiver must be removed or allowed for in measuring sensitivity. A sharply-tuned 400-cycle filter is interposed between the receiver output and the tube voltmeter. This voltmeter is a peak-reading linear instrument, and therefore any noise passing through the filter may usually be allowed for with sufficient accuracy by observing the meter reading for zero modulation and then adding this reading to the meter reading for 30% modulation. For example, if 8Ω is being used as the load resistor, the voltage required for standard output of 0.5 w is 2.0 v; if the average output with zero modulation is 0.5v, then the sensitivity will be read as the 30% modulation signal input which produces 2.5v output. This correction of the reading with the 400-cycle filter is necessary only in the case of receivers having unusually high noise levels.

Equivalent Noise Sideband Input ("Ensi").—This quantity is defined as "the voltage of a single 400-cycle sideband input which will produce an equal output from the receiver, other conditions being the same." The equation giving the "ensi" (a coined word) is $E_n = 0.3\ E_s\ (E_n^1/E_s^1)$, where $E_n$ is the desired ensi in microvolts, $E_s$ is the carrier level in microvolts, $E_n^1$ is the r-m-s output voltage of the noise alone with an unmodulated carrier applied to the antenna, and $E_s^1$ is the output voltage due to modulating this carrier 30% by a 400-cycle tone. The coefficient 0.3 is required because the test input is modulated 30%.

To obtain the ensi, the sensitivity is first determined with allowance for noise, as oulined above. This gives the value of $E_s$ in microvolts.

The corresponding 400-cycle output voltage gives the value of $E_s'$. The modulation is removed, the 400-cycle filter is disconnected, and the r-m-s voltage present due to noise is noted; this gives the value of $E_n'$ if a thermocouple instrument is used or if a suitable correction is applied for the particular tube voltmeter. The factor 0.65 is used as a correction for the linear-type tube voltmeters used in our measurements. The corresponding ensi may then be computed from the equation given above.

The values of $E_s'$ and $E_n'$ may be observed at a higher signal level since only their ratio enters. Our practice is to increase the carrier input at which the ensi measurement is made whenever the ensi exceeds 0.3 of the carrier input level used in taking the measurement. This precaution is taken so that the effective increase in noise power due to beats between the noise sidebands will be negligible relative to the power due to beats between the noise sidebands and the carrier.

Intermediate-Frequency Rejection Ratio.—The sensitivity of the receiver to the intermediate frequency is determined with the regular set-up used for overall measurements. After the i-f transformers have been aligned, the intermediate frequency with 30% modulation at 400-cycles, is introduced through the all-wave dummy antenna. The i-f sensitivity is measured with the receiver tuned at three points in each wave band. From these figures and the measured signal sensitivities at the same frequencies, the i-f rejection ratios are computed.

Image Ratio.—The sensitivity of the receiver to the image frequency is measured at several points in each wave band, and the ratio of the image sensitivity to the desired-signal sensitivity is recorded as the image ratio. This ratio is often called the "+2i.f." image ratio because the image frequency is ordinarily higher than the signal frequency by twice the value of the intermediate frequency.

There are other spurious responses, called higher-order responses, caused by beats between the harmonics of the oscillator and either the fundamental of an interfering signal or the harmonics of that signal which are generated in the receiver, but these are not usually measured in a routine set analysis.

Adjacent-Channel Selectance Ratio.—In the United States the broadcasting channels are separated by 10 kc. It is of interest, therefore, to determine to what extent the receiver discriminates against signals 10 kc away on either side of the desired channel. The regular set-up for the overall sensitivity measurement is used, and the signal is applied through the dummy antenna at a frequency (1) 10 kc below and (2) 10 kc above the frequency to which the reciever is tuned. The signal input required for standard output for each of these adjacent-channel signals is determined, and the ratio of each of these inputs to the corresponding desired-signal sensitivity is recorded as a ratio called the "adjacent-channel selectance ratio." This measurement is made at 600, 800, 1000, and 1400 kc in the broadcast band, and at corresponding points in the long wave band if one is provided.

Harmonic Measurements.—In conjunction with a wave analyser, such as the General Radio type 636-A, connected to the output of the receiver, a distortion analysis is made. With the regular set-up for overall measurements, three sets of measurements of per cent. harmonics are taken. The first set of measurements consists of keeping the signal input constant at 5000uv, with 30% modulation at 400 cycles, and varying the power output of the receiver from a low level to maximum power, in several steps. The second set consists of keeping the signal input constant at 5000uv and the watts output constant at some convenient low level, and varying the modulation to 10%, 50%, and 80% or 100%. In the last set of measurements, the output and per cent. modulation are kept constant, the former at a convenient low level and the latter at 30%, and the input is varied to 1000uv, 10,000uv, 100,000uv and 1 volt. These last figures are subject to change, as receivers of special types may require different levels.

The total per cent. harmonic distortion is calculated as the square root of the sum of the squares of the individual per cent. harmonics.

Tests on Mechanical Push-Button Tuning Mechanisms.—When sets are provided with mechanical push-button tuners the buttons are all set up to tune a 1300 kc signal to zero beat with another generator which is set to the receiver's normal i.f. For each button, the gang is opened, the button actuated, and the resultant beat noted as a frequency error; this is repeated several times, then the gang is closed and an equal number of measurements made from the closed position. Finally measurements are made with the gang alternately opened and closed, before actuations of the push-button. All the resultant deviation measurements for each button are averaged, taking account of sign, and the result recorded as "setting error." The setting errors of all the buttons are averaged without regard to sign to secure the "probable setting error."

The deviations of all the errors for each button from the figure representing the setting error for that button are averaged without regard to sign and recorded as "probable tuning deviation." The probable tuning deviation for all the buttons are then averaged arithmetically to give the "average probable deviation."

Two-Signal Selectivity.—This measurement is taken at 1000 kc for two values of desired signal input; for home sets, 5000uv and 1 volt, and for auto sets 5000uv and 0.2 volts. The 1000-kc signal is tuned in with the volume control set so that 1% modulation will produce a medium strength audio output. Modulation is then removed from the 1000-kc signal, and interfering signals from another generator, modulated 30%, are introduced at such amplitude as will result in the same output as was previously secured with the 1%-modulated desired signal. The interfering signal measurements are taken at every channel on both sides of 1000 kc up to 100-kc difference from 1000 kc, unless the signal input required reaches 1.5 volts before the 100 kc has been covered.

Output Characteristics.—The measurement is made at 1000 kc with a dummy output load, and the receiver adjusted for maximum sensitivity. The signal is modulated with 400 cycles successively at 0%, 10%, and 30%. The signal input is varied from 1uv to 1 volt and the audio output is plotted against the corresponding signal input. The set-up is the same as for the sensitivity measurement except that the 400-cycle filter is not in circuit. Usually, however, the portion of the

30% curve below the overload level is also taken with the filter in the circuit to show the shape of the output curve with the masking effect of a high noise output removed. The 0% output curve indicates the noise output of the receiver at full sensitivity, and also indicates the presence of hum modulation and motorboating at high signal levels.

A-V-C Characteristic.—This measurement is made at 30% modulation in the same way as the output measurement, except that the receiver volume control is adjusted so that the audio output voltage at 1 volt signal input does not exceed about 0.7 of the corresponding output measured in the output test, and the 400-cycle filter is in the circuit in all cases when the noise is sufficiently high to make a difference in the low-input end of these curves.

Overall Electrical Filedity.—The regular overall measurement set-up is modified in this test only by the fact that the r-f signal generator is modulated 30% by an a-f signal generator of variable freq., and, of course, by the removal of the 400-cycle filter from the output circuit. For this test the standard carrier frequency is 1000 kc and the signal input is 5000uv. The receiver volume level control is adjusted to give a value well below the overload condition. In plotting electrical fidelity curves it is customary to use the audio output at 400 cycles, with the tone control adjusted to give maximum high-frequency response, as the reference (or 100%) value. The output at frequencies of 30, 40, 50, 70, 100, 150, 200, 300, 400, 500, 700, 1000, 1500, 2000, 3000 cycles, and up in 1000-cycle steps, is plotted on a curve as a percentage of the above-mentioned standard. If there is an adjustable tone control, the first curve is taken with the tone control adjusted for maximum high-frequency response (100% at 400 cycles); any other required curves are then taken, usually without readjusting the volume level control. As many curves of electrical fidelity are taken as are considered necessary to represent the effect of the various fidelity-control means provided on the receiver.

SINGLE-STAGE MEASUREMENTS:

Antenna Coupling or Preselector.—The gain from the antenna to the grid of the first tube is measured at all the regular test frequencies within the range of the receiver, and is recorded as a voltage ratio, u. The total width of the resonance band at half maximum gain is measured at three points in each frequency band. An unmodulated r-f signal is introduced through a dummy antenna and the r-m-s voltage developed across the output terminals of the circuit is measured by the portable type of tube voltmeter previously described. Bandwidths at half maximum gain are measured with constant output. If there are two tunable circuits between the antenna and the grid of the first tube, gain and bandwidth measurements are also made on the first circuit alone.

When there are in the receiver two tunable circuits operating at signal frequency, such as a two-circuit preselector, or an antenna circuit and an r-f interstage circuit, reactance meter measurements are made to determine the degree of misalignment between the coils of the two circuits. The tuning condenser in the receiver is set at minimum capacity and the coils are successively tuned to the desired frequency by the condenser in the reactance meter. The recorded data show the number of micromicrofarads of shunt capacity which must be added to or subtracted from the antenna tuned circuit at each test frequency to bring it into exact alignment with the second tuned circuit. The measurements furnish a convenient means for determining whether it is necessary to alter the coil inductances and also for checking the effects of such changes.

The above measurement and the one described immediately below are made on the "reactance meter," described briefly earlier in this report. In the above test, the condition of zero beat is obtained with the r-f tuned coil of the receiver connected across the beating oscillator terminals of the reactance meter. The antenna tuned coil is then substituted across the beating oscillator terminals, the beating oscillator is retuned to zero beat, and the capacity change in uuf necessary to accomplish this result is recorded. These measurements are made at the normal test frequencies for each band after first adjusting the parallel trimmer condensers to bring the circuits into alignment at the high-frequency end of each band. The tuning condenser gang is set at minimum for the duration of this test, to eliminate the effect of misalignment between different sections. The alignment measurement is thus restricted to the characteristics of the coils alone, with most circuits.

The other alignment measurement of the antenna tuned circuit is made to show the effect upon the antenna alignment of various values of antenna capacity. For this measurement the antenna tuned circuit is connected across the terminals of the beating oscillator, with the gang condenser set at minimum, as before. A standard dummy antenna having a variable capacity is connected across the primary of the antenna coil under test. Zero beat is produced initially at each test frequency with 200-uuf dummy antenna capacity. The dummy antenna capacity is then changed to various values above and below 200 uuf and the incremental capacity required in the tuned circuit to produce zero beat is recorded as the indication of misalignment of the antenna circuit. The test frequencies used are 550, 600, 700, 1000 and 1400 kc for the medium-wave band, for antenna circuits having a high-inductance primary or a common series condenser; the 700-kc and 1000-kc points may be omitted if the alignment is good at 600 kc. If the antenna primary circuit is resonant above 1500 kc the test points are 600, 1000, 1200, 1400, and 1500 kc; in this case the 1000-kc and 1200-kc points may be omitted for circuits with good alignment at 1400 kc. Corresponding values are used in the long-wave band if one is provided. The values of the antenna capacitance normally used are 60, 100, 200, 300, 500 uuf and short circuit, but appropriate values are chosen for receivers intended to operate from antennas having characteristics substantially different from normal.

R-F Stage Measurements.—The voltage gain from the grid of each r-f amplifier tube to the secondary of the following interstage coupling transformer is measured at all the regular test frequencies within the range of the receiver and is recorded as a ratio, u. The resonance bandwidth at half maximum gain is measured at three points in each frequency band, with constant output. An unmodulated r-f signal is applied to the grid of the amplifying tube, taking care not to remove the normal grid bias.

The r-m-s voltage developed across the output terminals of the inter-stage coupling circuit is measured by a tube voltmeter of the portable type. The receiver power supply is of course turned on during the measurement, and the a-v-c system is disabled.

Precaution for Stage Measurements in A-V-C Receivers.—When the signal generator is connected to the grid of a tube, replacing a grid circuit which normally returns to the a-v-c string, the generator is connected through a condenser, with a leak resistor returning to the a-v-c circuit. This precaution is taken even though the a-v-c may, eventually return to ground, because otherwise the readings may be in error as a result of the initial a-v-c voltage caused by the space current due to the velocity of emission of electrons from the diode cathode.

Conversion Gain.—The conversion gain of a superheterodyne modulator is the ratio of r-m-s voltage of intermediate frequency at the grid-circuit terminals of the first i-f transformer to the r-m-s input voltage of signal frequency applied at the grid of the modulator tube.

An unmodulated r-f signal is applied to the grid of the modulator tube, and the r-m-s output voltage is measured with the portable tube voltmeter across the secondary of the i-f transformer. The a-v-c system is disabled for this measurement. This test is made at all the regular test frequencies within the range of the receiver.

Measurements of the Superheterodyne Oscillator.—The oscillator voltage tabulated in our reports is the d-c voltage across the oscillator grid leak, as calculated from the resistance value and the measured current flowing through it when the oscillator is working. This voltage is measured for each of the test frequencies throughout the range of the receiver. If the oscillator circuit necessitates some other method of voltage measurement, the procedure followed is described in the report covering the receiver.

The alignment between the oscillator tuned circuit and the signal-frequency tuned circuits is usually measured as follows:

The 400-cycle audio amplifier, described previously in this report is inserted in series with the +B lead to the i-f transformer in the plate circuit of the modulator tube in the receiver. A 400-cycle modulated signal, at the high-frequency alignment point of the tuning range under test, is introduced into the receiver through a dummy antenna. The receiver tuning dial is set to correspond to the generator frequency. Maximum output is produced at the loudspeaker or output meter by adjusting the parallel trimmers on the oscillator, r-f, and antenna tuned circuits. The signal generator is then set to the low-frequency alignment point, the oscillator is stopped by shunting its tank circuit with 400Ω, and the receiver tuned to give maximum response in the headphones of the 400-cycle amplifier. The oscillator is then started and its series padder adjusted to give maximum output from the receiver; for this adjustment the input signal is reduced to avoid overload effects or undue a-v-c action. The procedure for obtaining exact oscillator alignment at the alignment points as described above may have to be repeated, because of the inter-dependence of the two adjustments, before simultaneous alignment at both points is obtained.

After exact alignment is obtained at the alignment points, the usual test frequencies are applied through a dummy antenna. At each test frequency, the signal-frequency circuits of the receiver are tuned to the generator, with the oscillator stopped, by using the phones and listening to the modulation. The oscillator is then started, and the signal generator tuned for maximum output at the loudspeaker or output meter. The number of kilocycles by which the generator has to be changed to bring the overall output to a maximum is, of course, equal to the number of kilocycles by which the oscillator is misaligned with the r-f tuned circuits. The direction of the generator frequency change indicates the direction of the oscillator error, which is recorded in the data with a plus (+) sign to indicate that the oscillator is at a frequency above that required by the r-f circuits, or by a minus (-) sign if its error is in the other direction. The oscillator alignment is measured at all the standard test frequencies on all ranges of the receiver; of course each range is individually adjusted for alignment at the proper points before measuring the alignment errors for that range.

Precaution on Measurement of Oscillator Alignment.—When the cascade selectivity of the r-f circuit is comparable to the selectivity of the i-f system, the above procedure will indicate less misalignment than is actually present. The reason for this difficulty is that the combined response of two similar resonance curves, having different peak frequencies, either has a maximum between the component peaks, or is double-peaked. The procedure described above will in such cases show an apparent oscillator misalignment which is in error because it indicates the difference between the location of the combined peak and the r-f peak, and not the desired difference, which is that between the r-f peak and the i-f peak.

If the signal generator can be connected to the modulator grid without changing the frequency of the local oscillator in the receiver, an oscillator alignment measurement can be made by the following procedure, which is independent of the r-f selectivity. The initial observation with the receiver oscillator stopped is made as usual. The signal generator is then connected to the modulator grid, the oscillator is started, and the signal generator tuned for maximum response in the loudspeaker or output meter. The frequency difference between the first and second generator settings is, as before, equal to the oscillator misalignment with respect to the r-f tuned circuits.

Stage Measurements at Intermediate Frequency.—The gain and the bandwidths at one-half and one-tenth of maximum gain are measured at intermediate frequency through the modulator. An unmodulated i-f signal is applied to the modulator grid, and the output voltage measured across the secondary of the i-f transformer using the portable tube voltmeter. The resonance bandwidths are measured using the constant-output method. These measurements are made with the local oscillator of the receiver operating and the receiver tuned to about 1 Mc.

The gain and the bandwidth (at $W_2$ and $W_{10}$) are measured for each of the i-f stages, with the same general procedure as given in the preceding paragraph; where a stage is intended to feed a diode, the diode is connected and operating with its normal load while the measurements are made.

ADDITIONAL MEASUREMENTS.

Detector Sensitivity.—The detector sensitivity is the 30% modulated r-m-s signal voltage which must be applied to the detector tube to produce the standard a-f output across a dummy load. It is, of course, an indication of the total a-f gain.

The detector sensitivity is usually determined indirectly, by measuring the sensitivity at the last i-f grid for standard output and multiplying this sensitivity by the measured gain of the last i-f stage.

Hum Voltage.—The r-m-s value of the output voltage produced by hum in a-c operated receivers is measured by switching the "Hum-Output" switch on the output load box to the "Hum" position and, with the 400-cycle filter out of the circuit, reading the voltage directly on the linear type tube voltmeter. In this measurement the tone control is adjusted to give normal fidelity. If any fidelity control is provided which is capable of raising the hum output another measurement is made with this control set to give maximum voltage. If the polarity of the power plug affects the hum, readings are taken for both polarities.

Condenser Gang Alignment.—When the overall measurements indicate more misalignment than can be accounted for by the measured coil misalignment, the alignment of the gang condenser is checked on the reactance meter, and the corrections in micro-microfarads required to bring the other sections into equality with the section arbitrarily chosen as a reference are recorded. If the condenser misalignment exceeds the normal tolerances, the plates are usually knifed to bring its alignment to normal and the overall measurements repeated.

D-C Potentials.—The principal d-c potentials are measured at significant points throughout the circuit, and tabulated in the report. They are made directly after the "as received" measurements. The line voltage is adjusted to 230 volts.