

**Instruction**

**manual**

**Beckman** **SHOP**

INSTRUCTION MANUAL

WWV RECEIVER

MODEL 905

**Beckman**<sup>®</sup>

*Berkeley Division*

INSTRUCTION MANUAL

WWV RECEIVER  
MODEL 905

Serial No. \_\_\_\_\_

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## DESCRIPTION

The Beckman/Berkeley Model 905 WWV Receiver is a high quality instrument designed to conveniently and accurately utilize the standard time and frequency broadcast of National Bureau of Standards' radio stations WWV and WWVH. Carefully designed for optimum operation at these frequencies, this receiver provides laboratories and industries with primary standard times and frequencies through the use of a compact, convenient and reliable unit.

The Model 905, incorporating 6 individual crystals for maximum convenience, accuracy and stability, receives all six WWV broadcast frequencies, maintaining high selectivity and sensitivity, extremely stable tuning and excellent image rejection. This complete coverage permits reception even under adverse conditions. A logarithmic signal strength meter is provided for precise tuning. Local signals can be accurately measured by observing a zero beat on the meter or aurally monitoring the internal loudspeaker. An audio output jack is also provided for headphones or external reproducing devices. The internal loudspeaker can be disconnected by means of the SPEAKER switch on the front panel of the instrument.

For maximum convenience all controls are front panel mounted. Any one of the six WWV frequencies may be selected by means of a single front panel switch without the necessity of changing coil assemblies, crystals, etc. Audio filters are readily selected in the same manner. RF, audio gain, tuning and limiter threshold controls are conveniently positioned.

The highest quality components are used throughout, assuring long and reliable service. This precision instrument is available as a standard rack mounting unit or complete with its own cabinet for bench use.

The receiver is a 13-tube, high-selectivity, dual-conversion superheterodyne type. Input from the antenna is fed through one stage of RF amplification before being combined in a low noise mixer with the signal from a high stability crystal controlled local oscillator. The resulting relatively high IF frequency, 1.6 Mcs provides excellent image rejection. After amplification at this frequency, a second heterodyning process reduces the signal frequency to 50 Kcs for effective sideband discrimination. The local signal for this second heterodyning process

is obtained from a highly stable local oscillator, the frequency of which may be varied slightly by means of a front panel control to allow for absolute maximum receiver sensitivity and extremely precise tuning. Once set on any WWV frequency, this control requires no further adjustment.

After amplification at 50 Kcs, the signal is detected by an infinite impedance type of detector having a large dynamic range and negligible distortion. The intelligence, now having been removed from the carrier, is next fed to a variable threshold limiter in which any large noise pulses are significantly reduced. This is followed by a high gain negative feedback amplifier which provides for selective transmission, and finally the selected audio signal reaches a power output stage which drives the loudspeaker. Automatic gain control is provided by a separate high-gain amplifier which receives its signal immediately before the detection process. This amplifier serves to keep the output of the receiver nearly constant in spite of a widely varying input signal strength and also to drive the signal strength meter. When signal strength permits, the automatic gain control amplifier may be switched out, allowing manual control.

Because of modular construction, this unit possesses a number of distinct advantages:

1. High degree of mechanical strength owing to number of angular type structures. Flexure and bending minimized.
2. Neat appearance.
3. Unexcelled serviceability.
4. Simple replacement of an entire subassembly.
5. Easily adapted to special requirements.

## SPECIFICATIONS

### Frequency Coverage:

2.5, 5, 10, 15, 20 and 25 Mcs selectable by a single front panel switch

### Sensitivity:

1 $\mu$ v will produce AGC action on any band

### Selectivity:

Approx.  $\pm 1$ Kc at -3db without audio filters, allowing clear passage of WWV time "ticks"

Audio Filter Characteristics:

Initial Slope of Rejection Filters: Better than 70 db/octave

Selectivity at 3 db down: approx. 50 cps; at 6 db down: approx. 100 cps

Ratio of response to selected WWV tone to any other WWV tone: approx. 20 db

Rejection of frequencies off selected frequency: better than 30 db

Output Impedance:

3.2 ohms

Image Rejection:

Approx. 60 db

Antenna Inputs:

Single ended or balanced, 300 ohms (nominal)

Tube Complement:

one-5Y3GT

one-6AS6

one-6J6

one-6AN8

three-6BA6

two-12AT7

one-6AQ5

one-6CG7

two-12AU7

Power Requirements:

105 to 130 volts, 50 to 60 cps, approx. 125 watts

Mounting:

Cabinet or standard 19" relay rack size

Outside Dimensions:

Rack: 5 - 1/4" high x 19" wide x 13 - 3/4" deep - 18 lbs.

Cabinet: 7 - 1/4" high x 21" wide x 14 - 1/2" deep - 25 - 1/2 lbs.

INSTALLATION

Antenna. The antenna terminals are located at the rear of the receiver. In areas where the signal to be received is relatively strong, a long piece of wire attached to one terminal marked ANT will serve as an antenna. In this case connect the other ANT terminal to the GND terminal. Where the signal is weak, a half-wavelength folded dipole may be required. In this case connect the antenna to both ANT terminals with a piece of 300 ohm twin lead.

Shielded twin lead will reduce interference caused by any undesired radiation which may be present. Connect the shield to the GND terminal.

The GND terminal is connected through the chassis to a third wire on the power cord. If this wire is grounded to conduit at a power outlet, the GND terminal need not be separately connected to ground. However, if the third wire is not grounded, reception may be improved by connecting the GND terminal to an earth ground.

In rare instances in which signal strengths are extremely low or interference is high, a specialized antenna may be required. Consult appropriate texts.

Tuning RF Amplifier Grid Coils. After an antenna is installed and connected, the receiver input coils should be adjusted to match the peculiarities of the antenna. These coils are tuned by six slug adjustments on top of the receiver chassis marked "R. F. AMP GRID COILS." Do not disturb any other slug adjustments located nearby.

Tune the grid coils as follows:

1. With receiver energized, turn RF GAIN control to AGC.
2. Place the output leads from an accurately calibrated signal generator near the antenna input terminals. Place the BAND SWITCH at 2.5MC and tune the signal generator to 2.5Mcs. Vary the signal generator frequency slightly until the SIGNAL STRENGTH meter is deflected to a maximum. (Reduce signal generator output amplitude if necessary to keep meter on scale).
3. Adjust the 2.5Mc R. F. AMP GRID COIL(T106) for a maximum deflection on the SIGNAL STRENGTH meter. Do not disturb the tuning of the amplifier plate tank or the oscillator tank.
4. Repeat steps 2 and 3 for each BAND SWITCH frequency.

## OPERATING CONTROLS, CONNECTORS AND INDICATORS

### POWER toggle Switch and Indicator

Power applied when switch is on and indicator is lit.

### BAND SWITCH

Tunes receiver to frequency indicated.

### RF GAIN Control

Varies gain of RF and IF amplifying stages. When turned clockwise toward "AGC" until a switch clicks audibly, gain will be controlled automatically.

### OSC TUNING Control

Corrects any error in second IF frequency so that it will pass through narrow bandpass amplifier with maximum gain. Tune for maximum on SIGNAL STRENGTH meter with RF GAIN at AGC.

### RELATIVE SIGNAL STRENGTH Meter

Indicates antenna signal strength. Deflection is proportional to log of peak amplitude. The meter is operative only when RF GAIN control is turned to AGC.

### LIMITER Control

Determines the amplitude at which positive peaks of the audio signal are clipped. Clipping removes noise peaks. Turn clockwise to clip at lower amplitude. Too much clockwise rotation will distort desired audio signal.

### AUDIO GAIN Control

Varies gain of audio amplifier.

### AUDIO FILTER Switch

The position of this switch determines the frequency response of the audio amplifier. At the FLAT position response is constant within  $\pm 3$ db from 20 to 10,000 cps. At other positions the response is peaked about 30db at the indicated frequency.

### AUDIO OUT Jack

The same audio output signal that drives the loudspeaker is available at this jack for earphones.

### EXT SIG Jack

This terminal is capacitively coupled to the input grid of the receiver. Local signals may be introduced here for comparison with WWV frequencies.

## OPERATING PROCEDURE

Applying Power. To apply power to the receiver simply plug the line cord into a socket supplying 105 to 130 volts at 50 to 60 cps and turn the POWER switch ON. After a one-minute warmup the local oscillators will be sufficiently stable to permit tuning.

Tuning. Turn the BAND SWITCH to the frequency you wish to receive. Turn the RF GAIN fully clockwise toward AGC until a switch clicks audibly. In this position the gain of the RF and IF amplifiers is automatically controlled, with the result that the IF output is essentially constant regardless of the strength of the input signal. Adjust the OSC TUNING control for a peak reading on the SIGNAL STRENGTH meter. Adjust the AUDIO GAIN control for desired volume. The LIMITER control should be adjusted for a maximum audio signal to noise ratio. If this control is rotated too far clockwise, the audio signal may be distorted by the limiting action.

The gain of the RF and IF amplifiers may be adjusted manually with the RF GAIN control. As soon as this control is moved from the point labeled "AGC", automatic gain control ceases and the SIGNAL STRENGTH meter becomes inoperative.



Comparing Local Frequencies with WWV. For information on the characteristics of WWV signals and the time of transmission see the Bureau of Standards letter circular appended to this manual.

To compare an RF frequency with WWV apply the local signal to the EXT SIG jack. Place the AUDIO FILTER switch at FLAT. As the local frequency approaches WWV a beat frequency will be heard. When the beat frequency becomes too low to be audible, it will appear as a flutter on the SIGNAL STRENGTH meter provided the RF GAIN control is at AGC.

### OVERALL DESIGN

(Refer to Block Diagram)

The BAND SWITCH couples grid and plate tuned circuits to the RF amplifier and simultaneously couples a crystal and a plate tuned circuit to the first local oscillator. The selected amplifier grid and plate circuits are tuned to the WWV frequency desired. The oscillator crystal and plate circuit selected are tuned to a frequency 1.6Mcs off the WWV signal. The 1.6Mcs intermediate frequency produced is amplified and applied to the second mixer which receives a 1.65Mcs signal from the second local oscillator. This mixer generates a 50Kcs intermediate frequency which is amplified by the second IF stage.

The frequency of the second local oscillator may be varied slightly with a front-panel control to compensate for any frequency error in the 1.6Mc signal caused by the first local oscillator. This adjustment is necessary because a small percentage error in the 1.6Mcs frequency becomes an appreciable percentage deviation from 50 Kcs. For example, an error of 800 cps is only .005% of 1.6Mcs but 1.6% of 50Kcs. With this error the second local oscillator would be adjusted 800 cps off its nominal frequency in order to produce a precise 50 Kcs signal.

The 50Kcs intermediate frequency is led from the IF stage through an isolating cathode follower, then applied to the detector and to the AGC circuit. The output of the detector is the audio signal originating at WWV. The peaks of this signal are clipped by the limiter to reduce noise before further amplification.

The negative feedback path from the second to the first audio stage passes through an audio filter network except when the AUDIO FILTER switch is at FLAT. With the switch at FLAT, negative feedback is approximately equal for all audio frequencies. With the switch at 440, 600 or 1000 cps, a filter network connected in the feedback path attenuates the indicated frequency. Consequently, the overall audio gain at this frequency will be 20 or 30db higher than the gain over the rest of the audio spectrum.

The RF GAIN control varies the cathode resistance of the RF amplifier and both IF amplifiers. Turning this control fully clockwise actuates a switch

which applies the AGC voltage to the grids of these amplifiers. The AGC voltage is applied to the SIGNAL STRENGTH meter only when the RF GAIN control is fully clockwise.

## GENERAL MAINTENANCE

This receiver has been carefully built to give long, troublefree service and should require little attention. Periodically the signal strength meter should be adjusted to zero with the receiver deenergized. This is done by rotating a small screw in the meter face. Tubes must be replaced as they wear out and this may make it necessary to realign the stages involved. Otherwise the initial alignment made at the factory need not be disturbed.

## ALIGNMENT

### Equipment Required

1. RF signal generator, range: 50 Kcs to 25 Mcs
2. Frequency measuring equipment, range: 1500 Kcs to 25 Mcs, accuracy: 1 part in 1,000,000; preferably a counter-type frequency meter such as the Beckman/Berkeley Model 5571.
3. VTVM, range: 1 v to 150 v DC
4. Oscilloscope, frequency response to 30 Mcs, sensitivity 50 mv/cm. For example, Tektronix type 541 with 53K/54K plug-in preamplifier.

Alignment should be attempted only by someone who has had previous experience aligning shortwave receivers. If the entire receiver is to be aligned, tune stages in the order listed below. The IF output of the receiver may be observed at Pin 3 of V108A without detuning any of the previous stages due to loading effects. As a rule, however, it will be more convenient to align the receiver with the automatic gain control in operation, in which case the IF output will not vary appreciably. Whenever inserting a signal for alignment purposes, use the minimum amplitude which will produce an adequate indication.

Under automatic gain control, the amplitude of the AGC voltage at J105 will indicate how well the receiver is aligned. The amplitude will increase to a peak as each stage is brought more closely into alignment. Disconnect the antenna before aligning.

### Rough Alignment of 2nd IF Amplifier

1. Set controls as follows:  
RF GAIN control at AGC  
LIMITER control fully counterclockwise  
AUDIO FILTER switch at FLAT
2. Measure the AGC voltage at J105 with VTVM. This voltage can vary from approximately zero to -50 v DC.

3. Insert a 50 Kcs signal ( $\pm 50$  cps) at Pin 1, V105 through a blocking capacitor.
4. Adjust the two slugs on T110, located at the rear of the receiver, for maximum AGC voltage.
5. Move 50 Kcs signal to Pin 1, V104 and adjust two slugs on T109 for maximum AGC voltage.
6. Remove injected 50 Kcs signal.

#### Adjusting Frequency at 2nd Local Oscillator

1. Rotate the OSC TUNING capacitor (C151) until plates are half meshed.
2. Measure the frequency at Pin 7, V104 with a frequency measuring device accurate to .01 %.
3. Adjust L118 until frequency is 1650 Kc.

#### Rough Alignment of 1st IF Amplifier

1. Inject 1.6 Mcs signal ( $\pm 100$  cps) at Pin 1, V103 through a blocking capacitor.
2. Adjust both slugs on T108 for maximum AGC voltage at J105.
3. Move 1.6 Mcs signal to Pin 6, V102 and adjust both slugs on T107 for maximum AGC voltage.

#### Fine Alignment of Both IF Stages

1. Final tuning of IF stages requires an input IF signal of precisely 1.6 Mcs. Therefore, adjust signal generator as near 1.6 Mcs as possible using frequency measuring equipment accurate to 1 part in 1,000,000. Couple the output signal loosely to pin 6 of V102 to minimize loading effects. Placing output leads near V102 should create adequate coupling.
2. Adjust the OSC TUNING control for maximum AGC voltage at J105. (Very little adjustment should be required)
3. Trim slugs on all IF transformers (T107, T108, T109 & T110) for maximum AGC voltage. (Very little readjustment should be required.)

#### Adjusting Frequency of Crystal-controlled Local Oscillator

1. Measure output frequency of oscillator at Pin 7 of V102. Attach a 3.3K isolating resistor to this pin and couple the resistor through a coax cable to the input of frequency measuring equipment accurate to 1 part in 1,000,000.

2. Six oscillator tuning controls are located on top of the chassis and labeled "XTAL OSC TANKS". Tune each control for the proper oscillator output frequency. All frequencies should be within  $\pm 2340$  cps of the figure given below.

<u>Control</u>	<u>BAND SWITCH Position</u>	<u>Proper Oscillator Frequency</u>
L112, 2.5MC	2.5MC	4.10Mcs
L111, 5MC	5MC	6.60Mcs
L110, 10MC	10MC	8.40Mcs
L109, 15MC	15MC	13.40Mcs
L108, 20MC	20MC	18.40Mcs
L107, 25MC	25MC	23.40Mcs

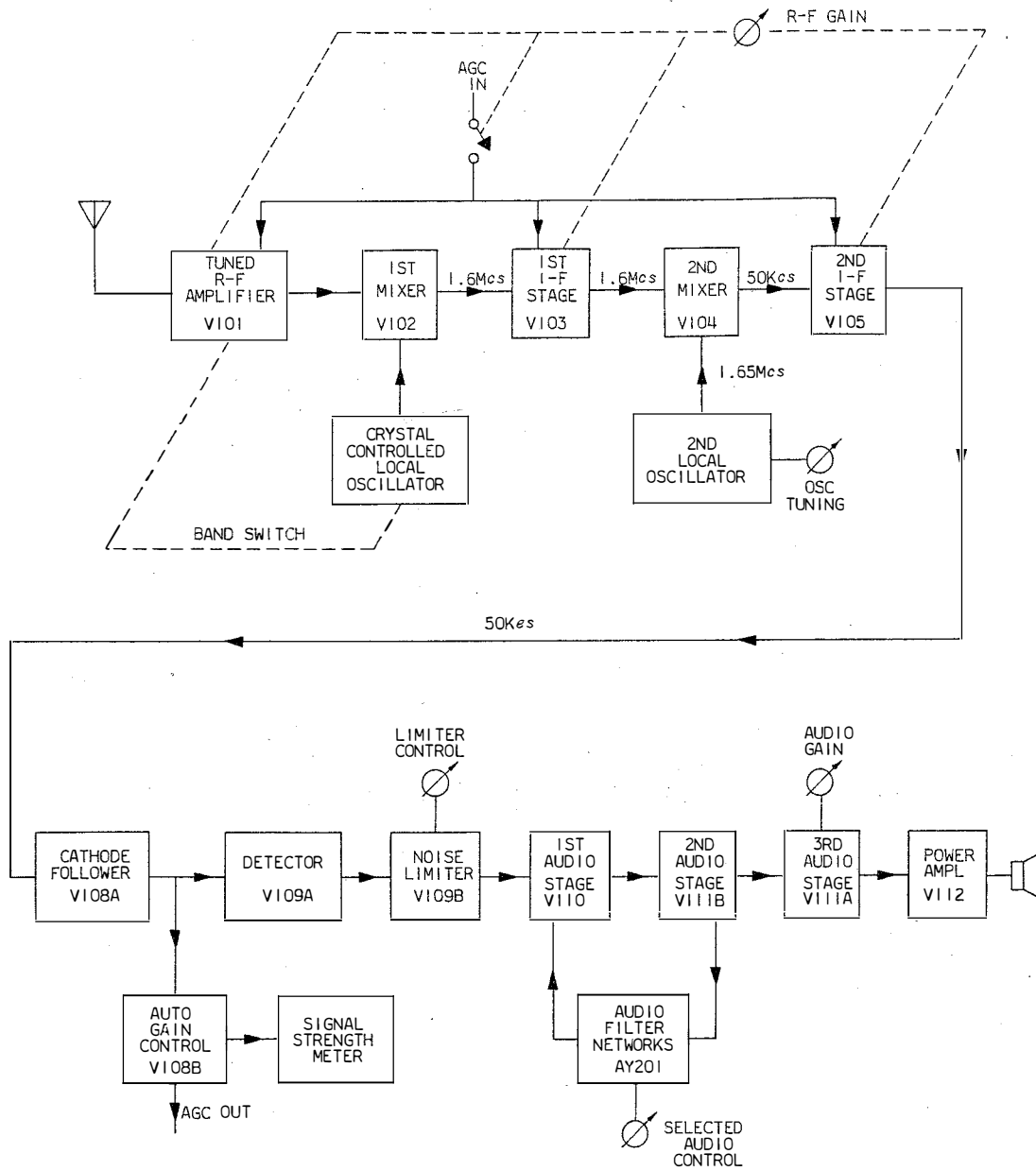
#### Aligning the RF Amplifier

The RF amplifier alignment controls are located on top of the chassis labeled "RF AMP GRID COILS" and "R. F. AMP. PLATE TANKS."

1. With BAND SWITCH at 2.5MC, couple a signal generator to the antenna terminals and adjust the output frequency of the signal generator to as near 2.5Mcs as possible using highly accurate frequency measuring equipment.
2. Adjust 2.5MC grid coil (T106) and 2.5MC plate tank (L106) for maximum AGC voltage.
3. Align the other bands in a similar manner.

#### Testing Total Alignment.

Check to see that a 1-microvolt signal at the antenna terminals produces a detectable AGC voltage. The same signal modulated 30% should produce an audible loudspeaker tone with the AUDIO FILTER switch at FLAT and the AUDIO GAIN control fully clockwise.



BLOCK DIAGRAM

84.20  
June 1956

U. S. DEPARTMENT OF COMMERCE  
NATIONAL BUREAU OF STANDARDS  
BOULDER LABORATORIES  
BOULDER, COLORADO

Letter Circular  
LC1023  
(Supersedes  
LC1009)

STANDARD FREQUENCIES AND TIME SIGNALS  
WWV AND WWVH

The National Bureau of Standards' Radio Stations WWV (in operation since 1923) and WWVH (since 1949) broadcast six widely used technical services:

1. STANDARD RADIO FREQUENCIES,
2. STANDARD AUDIO FREQUENCIES,
3. STANDARD TIME INTERVALS,
4. STANDARD MUSICAL PITCH,
5. TIME SIGNALS,
6. RADIO PROPAGATION FORECASTS.

All inquiries concerning the technical radio broadcast services should be addressed to: National Bureau of Standards Boulder Laboratories, Boulder, Colorado.

The radio bands in which the foregoing services are broadcast are: 2500  $\pm$ 5 kc (2500  $\pm$ 2 kc in Region 1); 5000  $\pm$ 5 kc; 10,000  $\pm$ 5 kc; 15,000  $\pm$ 10 kc; 20,000  $\pm$ 10 kc; 25,000  $\pm$ 10 kc. These bands were allotted by international agreement, in 1947, for exclusive standard-frequency-broadcast use.

The National Bureau of Standards' radio stations are located as follows: WWV, Beltsville, Maryland (Box 182, Route 2, Lanham, Maryland); WWVH, Maui, Territory of Hawaii (Box 901, Puunene, Maui, T. H.). Coordinates of the stations are: WWV (lat. 38°59'33" N., long. 76°50'52" W.); WWVH (lat. 20°46'02" N., long. 156°27'42" W.).

The WWV - WWVH broadcasts are a convenient means of transferring the national standard of frequency and time interval and making it readily available throughout the United States and over much of the world. The broadcast program is shown schematically in Figure 1.

1. Standard Radio Frequencies:

Station WWV broadcasts on standard radio frequencies of 2.5, 5, 10, 15, 20, and 25 Mc. The broadcasts are continuous, night and day, except WWV is off the air for approximately 4 minutes each hour. The silent period commences at 45 minutes, plus 0 to 15 seconds, after each hour.

Station WWVH broadcasts on standard radio frequencies of 5, 10, and 15 Mc. The WWVH broadcast is interrupted for 4 minutes following each hour and half hour and for periods of 34 minutes each day beginning at 1900 UT (Universal Time, UT is the same as GMT and GCT).

The standard radio frequencies are widely used, e. g., by the communications and electronics industry, research laboratories, and government. A local oscillator may be set versus the received frequency, and any desired radio frequency, including microwave frequencies, may be accurately measured in terms of the standard. The beat frequency method, or variations of it, is generally used. With a very narrow band receiver the standard radio frequency can be used when the received field strength is too low for audibility on ordinary radio receivers.

The accuracy of each of the radio frequencies as transmitted is better than 1 part in 100,000,000. The stability (quality of remaining fixed or unvarying) at the transmitter is normally within 1 part in  $10^9$  at WWV and 5 parts in  $10^9$  at WWVH. Deviations at WWV are about 2 in  $10^{10}$  each day; frequency adjustments are made each day if necessary at 1900 UT. Deviations at WWVH are about 4 in  $10^{10}$  each day; frequency adjustments are made each day if necessary during the interval 1900 to 1935 UT. If received accuracies better than 3 parts in  $10^7$  are desired it is necessary to make measurements over a long interval, e. g., 24 hours, to obtain an accuracy of 1 part in  $10^8$ . Such long-interval measurements should preferably be of the type that result in a strip chart record of frequency or phase changes (local oscillator vs WWV or WWVH) during the measurement interval. During intervals of about 10 hours or less, one may obtain highest accuracy when ionospheric conditions are normal and when measurements are made at the optimum time of day which is when sunrise or sunset does not occur over the radio propagation path.

Final corrections to the broadcast frequencies are available on a quarterly basis from the National Bureau of Standards Boulder Laboratories, Boulder, Colorado.

## 2. Standard Audio Frequencies:

Two standard audio frequencies, 440 cycles per second and 600 cycles per second, are broadcast on each radio carrier frequency. The audio frequencies are given alternately starting with 600c on the hour for three minutes, interrupted two minutes, followed by 440c for three minutes and interrupted two minutes. Each 10-minute period is the same except for transmitter interruptions mentioned under 1 above.

The two standard audio frequencies are useful for accurate measurement or calibration of instruments operating in the audio or ultrasonic regions of the frequency spectrum. The frequencies broadcast were chosen because 440c is the standard musical pitch and 600c has the maximum number of integral multiples and sub-multiples; also, 600c is conveniently used with the standard power-frequency 60c.

Electronic circuits may be associated with radio receivers which automatically convert 600c to 1000c, 100c, etc.

The accuracy of the audio frequencies, as transmitted is better than one part in 100,000,000. Changes in the transmitting medium (Doppler effect, etc.) result at times in fluctuations in the audio frequencies as received.

### 3. Standard Time Intervals:

Seconds pulses at intervals of precisely one second are given as double sideband amplitude modulation on each radio carrier frequency. The pulse duration is 0.005 second. The pulse wave form is shown in Figure 2. At WWV each pulse consists of five cycles of a 1000c frequency. At WWVH each pulse consists of six cycles of a 1200c frequency. The pulse spectrum is composed of discrete frequency components at intervals of 1.0c. The components have maximum amplitudes at approximately 995c and 1194c for the WWV and WWVH pulses respectively.

The seconds pulses provide a useful standard time interval for quick and accurate measurement or calibration of time and frequency standards and timing devices. For example, a watch rate recorder may be checked by recording the seconds pulses. Intervals of one minute are marked by omitting the pulse at the beginning of the last second of every minute and by commencing each minute with two pulses spaced by 0.1 second. The two-minute, three-minute and five-minute intervals are synchronized with the seconds pulses and are marked by the beginning or ending of the periods when the audio frequencies are off.

A time interval as broadcast from WWV is accurate to 1 part in  $10^8$  plus or minus 1 microsecond. Received pulses have random phase shifts or jitter because of changes in the propagating medium. The magnitudes of these changes range from practically zero for the direct or ground wave to about 1000 microseconds when received via a changing ionosphere. Multiple pulses and echos are sometimes received because of propagation around the world and reflection from objects on the earth's surface. The beginning of the first pulse received, i. e., the part having least delay, is most accurate and should be used. When ionospheric conditions are normal and the correct time of day is chosen, a frequency standard can be checked in a few hours versus WWV with a precision of about 1 part in  $10^9$ ; however, it is best to use intervals of 24 hours when comparing with this precision.

In using the time interval markers for high precision work it is necessary to remember that step adjustments of precisely  $\pm 20$  milliseconds may be made at the transmitter on Wednesdays at 1900 UT; this is explained under part 5, Time Signals.



The seconds pulses from WWVH are adjusted if necessary each day during the interval 1900 to 1935 UT so as to commence simultaneously with those from WWV, within plus or minus 500 microseconds.

#### 4. Standard Musical Pitch

The frequency 440 cycles per second for note A above middle C has been the standard in the music industry in the United States since 1925. The radio broadcast of this standard was commenced by the National Bureau of Standards in 1937. It is now given six times per hour, 18 minutes per hour, from WWV and WWVH as shown in Figure 1. With this broadcast the standard pitch is maintained and musical instruments are manufactured and adjusted versus an unvarying standard. Listeners of music are benefited because there are fewer instruments not in tune and practically no instruments are manufactured which cannot be tuned to 440c.

A high frequency or short-wave radio receiver is the only equipment needed to effectively use the musical pitch standard.

#### 5. Time Signals:

The audio frequencies are interrupted at precisely two minutes before each hour. They are resumed precisely on the hour and each five minutes thereafter; they mark accurately the hour and the successive 5-minute periods (see Figure 1).

Time signals from WWV are maintained in close agreement with uniform time, called U. T. 2, determined by the U. S. Naval Observatory. This is done by occasional step adjustments in time, when necessary, of precisely plus or minus twenty milliseconds. These adjustments may be necessary several times per year. When required, they are made on Wednesdays at 1900 UT simultaneously at WWV and WWVH.

Universal Time is announced in telegraphic code each five minutes from WWV and WWVH. This provides a quick reference to correct time where a timepiece may be in error by a few minutes. The zero- to twenty-four-hour system is used starting with 0000 at midnight. The first two figures give the hour and the last two figures give the number of minutes past the hour when the tone returns. For example, at 1655 UT, or 11:55 a. m., Eastern Standard Time, four figures (1, 6, 5, and 5) are broadcast in code. The time announcement refers to the end of an announcement interval, i. e., when the audio frequencies are resumed.

At Station WWV a voice announcement of Eastern Standard Time is given before and after each telegraphic code announcement. For example, at 9:10

a. m., EST, the voice announcement in English is: "National Bureau of Standards, WWV; when the tone returns, Eastern Standard Time is 9:10 a. m."

Final corrections to the time signals, as broadcast, are determined and published, on a weekly basis, by the U. S. Naval Observatory, Washington 25, D. C.

#### 6. Radio Propagation Forecasts:

A forecast of radio propagation conditions is broadcast in telegraphic code on each of the standard radio carrier frequencies: from WWV at approximately 19.5 and 49.5 minutes past each hour, and from WWVH at approximately 9.4 and 39.4 minutes past each hour, as shown in Figure 1. Propagation notices were first broadcast from WWV in 1946; the present type of announcement has been broadcast from WWV since July 1952, and from WWVH since January 1954.

The forecast announcement tells users the condition of the ionosphere at the regular time the forecast is made and how good or bad communication conditions are expected to be in the succeeding 6 or more hours. The NBS forecasts are based on information obtained from a world-wide network of geophysical and solar observatories, including radio soundings of the upper atmosphere, short-wave reception data, and similar information. Trained forecasters digest the information and formulate the predictions.

From WWV the forecasts refer only to North Atlantic radio paths, such as Washington to London or New York to Berlin. The times of issue are 0500, 1200 (1100 in summer), 1700, 2300 UT. These are the short-term forecasts prepared by NBS-CRPL North Atlantic Radio Warning Service, Box 178, Ft. Belvoir, Virginia.

From WWVH the forecasts are for North Pacific radio paths, such as Seattle to Tokyo or Anchorage to San Francisco. The times of issue are 0200 and 1800 UT, with these forecasts first broadcast at 0239 and 1839 UT respectively. These are short-term forecasts prepared by NBS-CRPL North Pacific Radio Warning Service, Box 1119, Anchorage, Alaska. (Another short-term forecast at 0900 UT may be broadcast at a later date.)

The forecasters assume that the most suitable radio frequencies for communications are available and in use for the typical paths. Because of this assumption, their notices must be interpreted on a relative scale in terms of experience on each radio circuit in use. It is impossible to rate conditions on an absolute scale since the varied effects of transmitter power, type of communications traffic and procedure, antennas and receivers, prevent an evaluation which will be valid for all circuits. One purpose of broadcasting both a description and a forecast is to show more clearly whether propagation conditions are expected to deteriorate or improve in the coming period.

The forecasts broadcast by WWV and WWVH apply only to short-wave radio transmissions over paths which are near the auroral zone for a considerable part of their length. In this zone the ionospheric layers are very likely to be disturbed, and because short-wave, long-range radio transmissions are dependent on the condition of the ionosphere, communications may be disrupted. Often the ionospheric disturbance accompanies intense magnetic field variations and a brilliant aurora. The resulting propagation effects range from severe fading to a complete break in the communications link.

The forecast is broadcast as a letter and a digit. The letter portion of the announcement identifies the radio quality at the time the forecast is made. The letters denoting quality are "N", "U", and "W", signifying that radio propagation conditions are normal, unsettled, and disturbed. The digit portion is the forecast of the radio propagation quality on a typical North Atlantic (from WWV) or a typical North Pacific (from WWVH) transmission path during the 6 or more hours after the forecast is made. Quality is graded in steps ranging from 1 (useless) to 9 (excellent) as follows:

<u>Disturbed Grades (W)</u>	<u>Unsettled Grade (U)</u>	<u>Normal Grades (N)</u>
1 - useless	5 - fair	6 - fair-to-good
2 - very poor		7 - good
3 - poor		8 - very good
4 - poor-to-fair		9 - excellent

If, for example, propagation conditions at the time the forecast is made are normal but are expected to be only "poor-to-fair" within the next 6 or more hours, the announcement would be broadcast as N4 in international Morse code.

7. Radiated Power, Transmitting Antennas, Modulation:

Radiated power is shown in the table below:

<u>Frequency, Mc</u>	<u>Power, Kw</u> <u>WWV</u>	<u>Power, Kw</u> <u>WWVH</u>
2.5	1	
5	8	2
10	9	2
15	9	2
20	1	
25	0.1	

The broadcast on 2.5 Mc is from a vertical quarter-wave antenna. The broadcasts on all other frequencies are from vertical half-wave dipoles. The radiation is omnidirectional.

The percent amplitude modulation, double sideband, is:

audio frequencies 440 or 600 c/s	75%
voice and seconds pulses, peak,	100%

At WWV, the tone frequency 440 or 600 c/s, except on 25 Mc, is experimentally operated as a single upper sideband with full carrier. Power output from the sideband transmitter is about one-third the carrier power. Single sideband tone on 25 Mc may be added at a later date. Other signals (announcements and seconds pulses) are double sideband, 100 percent amplitude modulation.

#### 8. Accuracy:

Frequencies from WWV and WWVH are accurate to within 1 part in  $10^8$  as broadcast; this is with reference to the U. S. Naval Observatory time and is limited by uncertainties in the immediate determination of astronomical time.

The radio frequencies may be consistently received with accuracies equal to those transmitted for several hours per day during total light or total darkness over the transmission path at locations in the service range. This was described under 1. Standard Radio Frequencies.

Large errors are caused by motion of the radio receiver relative to the transmitting stations or by motions of the reflecting ionospheric layers on which long-distance radio propagation depends. For example, on a vehicle moving 60 miles per hour relative to a fixed station, the received frequency would be in error by about 1 part in  $10^7$ . Measurements made at NBS Boulder Laboratories and at WWVH have shown that during the course of the day errors in the received frequencies vary approximately -3 to +3 parts in  $10^7$ .

Daily deviations in frequency and time of stations WWV and WWVH are tabulated on a quarterly basis. These data are available on request. In Figure 2 are plotted time signal deviations extending back 7 years. The deviations may be considerably less commencing in 1956.

#### 9. Distance Range of Reception:

Of the standard radio frequencies (2.5, 5, 10, 15, 20 and 25 Mc), the lowest provide service to short distances, and the highest to great distances. Reliable reception is in general possible throughout the United States and the North Atlantic and Pacific Oceans, and reception at times throughout the world. One should select the frequency that gives best reception at any particular place and time. This can be done by two methods:

a. By tuning to the different frequencies and selecting the one most suitable at that time.

b. By making use of techniques of prediction of usable frequencies. NBS publications useful for this purpose are the reports of the CRPL-D series, "Basic Radio Propagation Predictions", which are issued monthly, three months in advance of the month of prediction, and Circular 465 of the National Bureau of Standards, "Instructions for the Use of Basic Radio Propagation Predictions". These two publications may be obtained from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., price in U. S. \$1.00 per year (12 issues) and 30 cents per copy, respectively (foreign, \$1.25, and 40 cents).

10. Other Standard Frequency and Radio Time Signal Services:

The U. S. Naval Observatory, Department of the Navy, broadcasts time signals at regular intervals from NSS (Annapolis, Maryland), NPG (Mare Island, California), NPM (Pearl Harbor, Hawaii), NBA (Balboa, Canal Zone). Detailed information may be obtained from the U. S. Naval Observatory, Washington 25, D. C.

The Dominion Observatory, Ottawa, Canada, broadcasts time signals continuously over Station CHU on frequencies of 3330, 7335 and 14670 kc. Information may be obtained by writing the Dominion Observatory.

A comprehensive list of United States and foreign radio time signals is given in chapter 3 of "Radio Navigational Aids", Hydrographic Office publication No. 205, for sale by the Hydrographic Office, Washington 25, D. C., price \$2.00, U. S. or foreign.

Standard frequencies and time signals are broadcast by other stations as indicated in the following table.

<u>Call Sign</u>	<u>Location</u>	<u>Carrier Frequency</u> Mc	<u>Modulation</u> c/s	<u>Carrier Power</u> Kw
LOL	Buenos Aires, Argentina	2.5, 5, 10, 15, 20 and 25	1, 440, 1000	2
ZUO	Johannesburg, South Africa	5	1 - -	0.1
ZLFS	Lower Hutt, New Zealand	2.5	- - -	0.035
-	Moscow, USSR	10 and 15	1 - -	- - -
MSF	Rugby, England	2.5, 5 and 10	1, 1000 -	0.5
JJY	Tokyo, Japan	2.5, 5, 10 and 15	1, 1000 -	1
IBF	Torino, Italy	5	1, 440, 1000	0.3
-	Uccle, Belgium	2.5	- - -	0.02

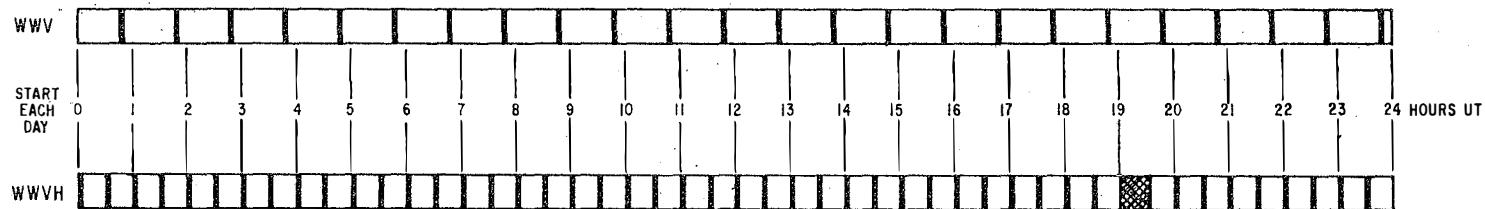
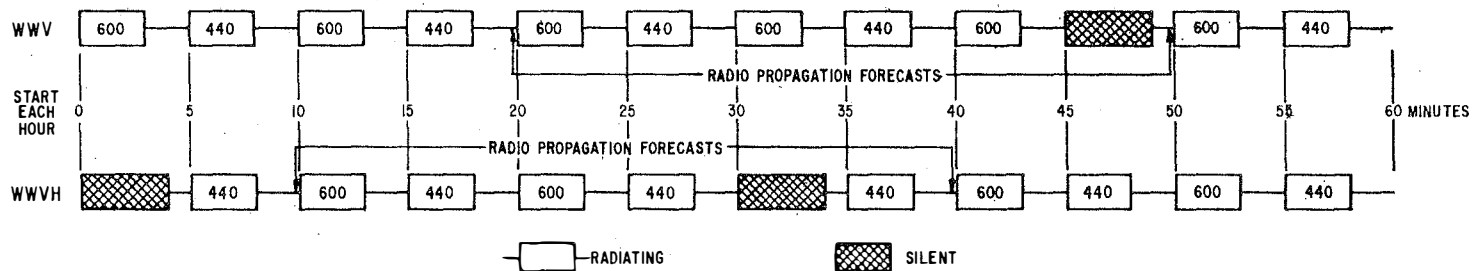
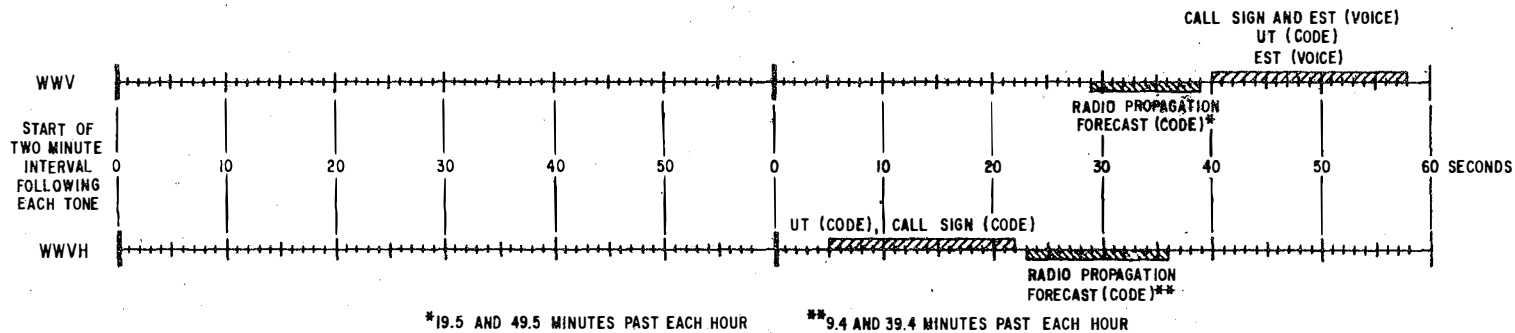
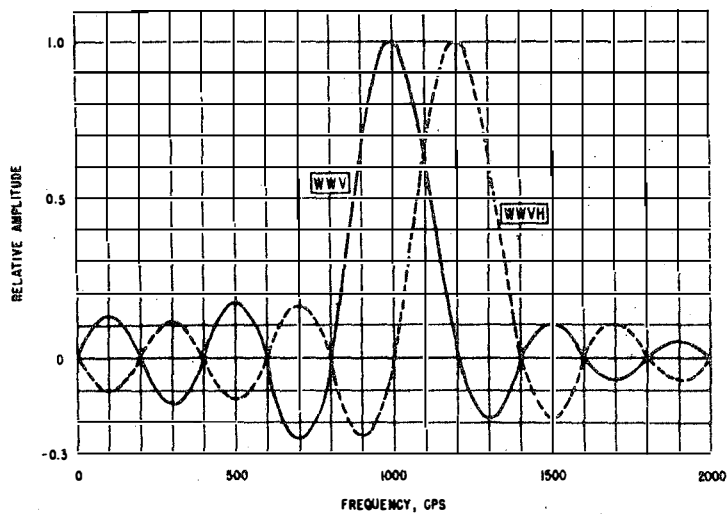
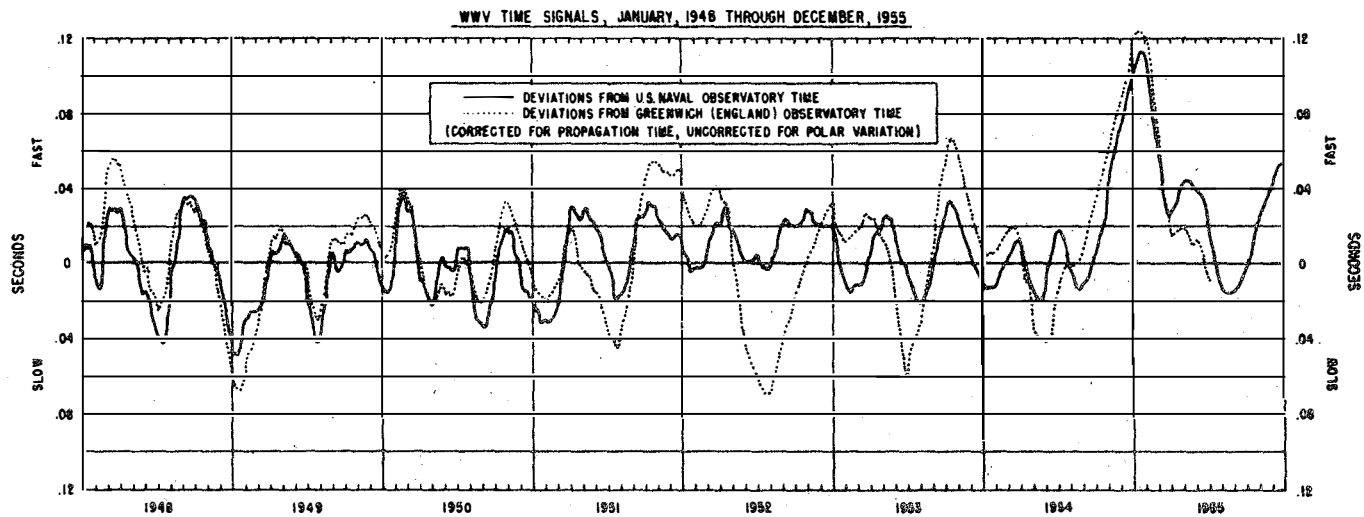


FIG. 1



THE FREQUENCY SPECTRUM  
OF THE  
WWV AND WWVH SECONDS PULSES

THE SPECTRUM IS COMPOSED OF DISCRETE FREQUENCY COMPONENTS AT INTERVALS OF 1.0 CPS. THE COMPONENTS AT THE SPECTRAL MAXIMA HAVE AMPLITUDES OF 0.005 VOLT FOR A PULSE AMPLITUDE OF 1.0 VOLT. THE WWV PULSE CONSISTS OF FIVE CYCLES OF 1000 CPS. THE WWVH PULSE CONSISTS OF SIX CYCLES OF 1200 CPS.

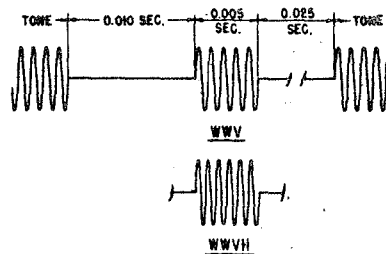
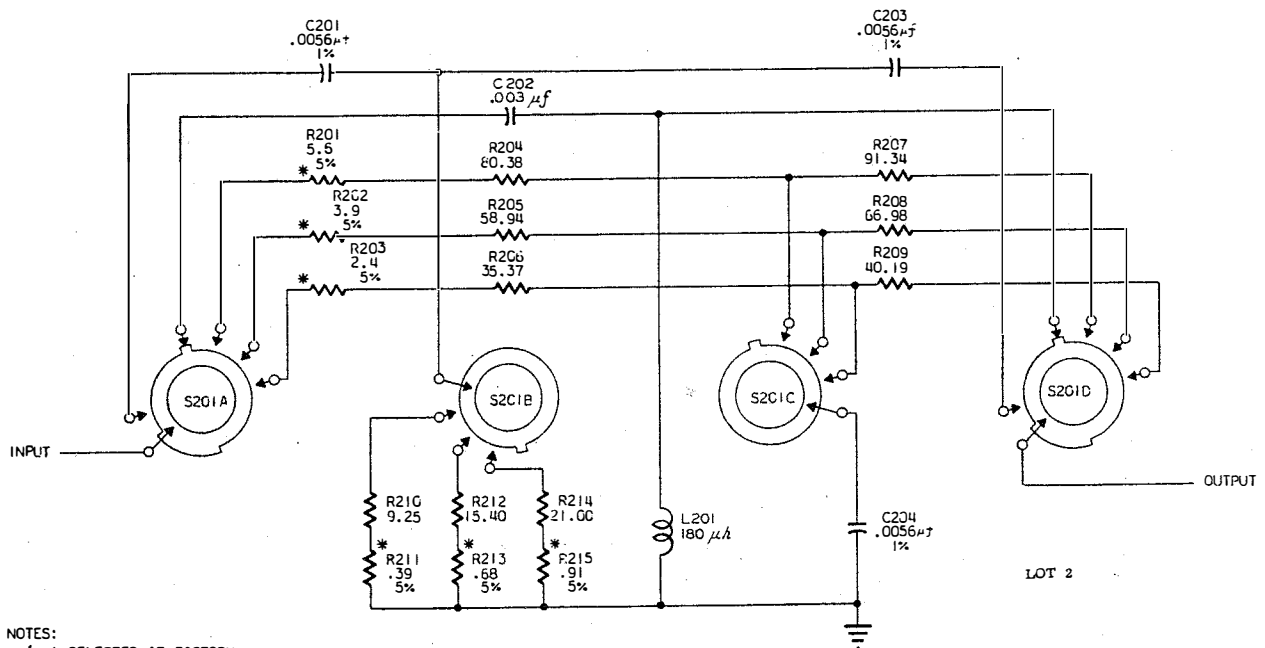


FIG. 2

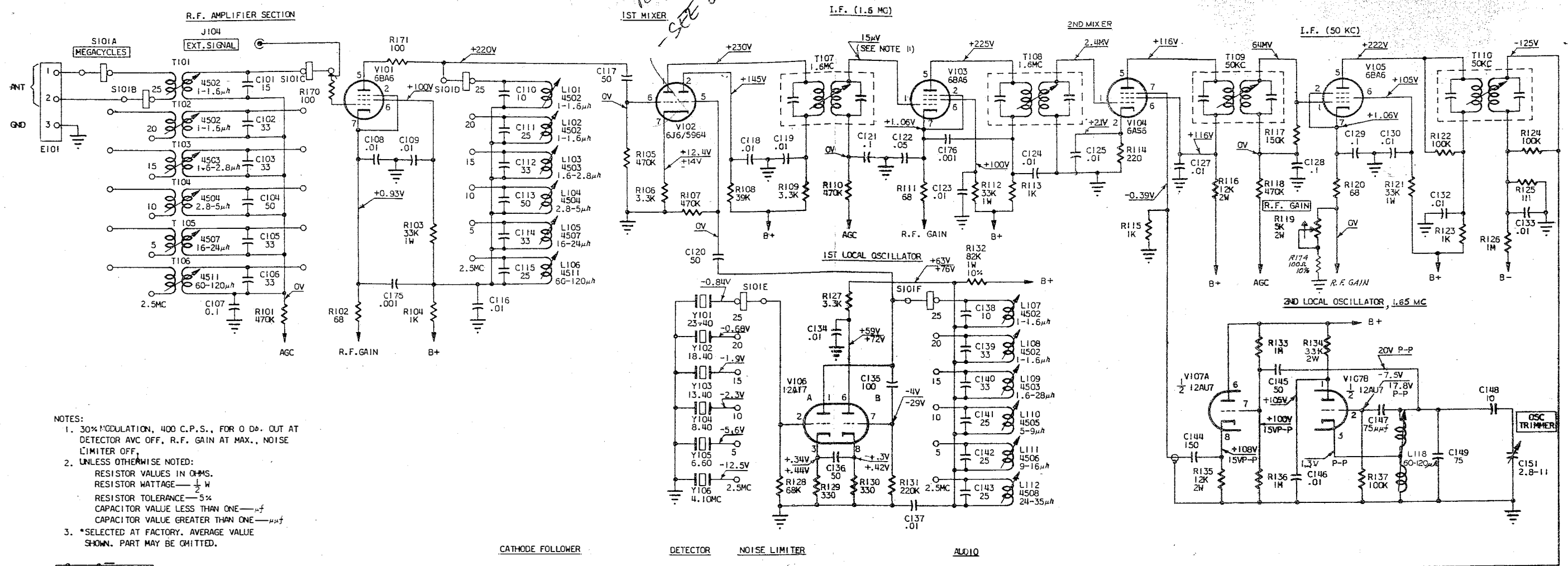


- NOTES:  
 1. \*-SELECTED AT FACTORY  
 2. ALL RESISTORS ARE IN KILOHMS,  
 $\frac{1}{2}$  W, 1% UNLESS OTHERWISE NOTED.

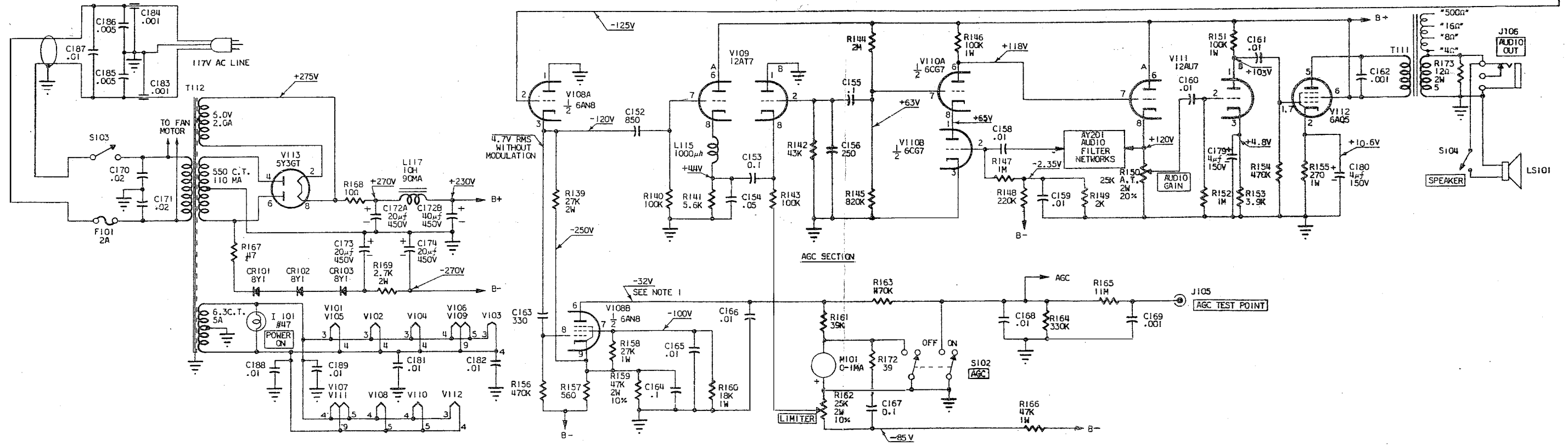
**SCHEMATIC DIAGRAM  
 AUDIO FILTER CIRCUIT  
 MODEL 905  
 DWG. NO. 905B2**



*CIRCUIT  
REPLACED  
- SEE OVERLEAF*



- NOTES:
- 30% MODULATION, 400 C.P.S., FOR 0 DB. OUT AT DETECTOR AVC OFF, R.F. GAIN AT MAX., NOISE LIMITER OFF.
  - UNLESS OTHERWISE NOTED:  
RESISTOR VALUES IN OHMS.  
RESISTOR WATTAGE — 1/2 W  
RESISTOR TOLERANCE — 5%  
CAPACITOR VALUE LESS THAN ONE —  $\mu$ f  
CAPACITOR VALUE GREATER THAN ONE —  $\mu$ mf
  - \*SELECTED AT FACTORY. AVERAGE VALUE SHOWN. PART MAY BE OMITTED.



OVERALL SCHEMATIC DIAGRAM  
MODEL 905 WWV RECEIVER  
DWG. NO. 905D1

# 1ST MIXER

