

INSTRUCTION MANUAL

STANDARD-SIGNAL GENERATOR

Type MS111



RADIOMETER

ELECTRONIC MEASURING INSTRUMENTS
FOR SCIENTIFIC AND INDUSTRIAL USE

INSTRUCTION AND OPERATING MANUAL
FOR

STANDARD-SIGNAL GENERATOR

Type MS111

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INTRODUCTION

The Standard-Signal Generator, type MS111, is a precision instrument for measurements at ultrasonic or radio frequencies.

Special attention has been paid to the modulation circuits so that modulation depths up to 80% are obtained with a typical distortion of only 1.5%.

Because the generator operates on the fundamental frequency there is complete freedom from subharmonics.

The generator's sturdy construction and the simplicity of its operation make it equally well suited for laboratory work and for production testing of radio receivers and allied electronic equipment.

SPECIFICATIONS

CARRIER FREQUENCY

Range

10 kc to 110 Mc in twelve direct-reading subranges:

10	-	22	kc	1	-	2.2	Mc
21	-	47	kc	2.1	-	4.7	Mc
46	-	110	kc	4.6	-	11	Mc
100	-	220	kc	10	-	22	Mc
210	-	470	kc	21	-	47	Mc
460	-	1100	kc	46	-	110	Mc

Accuracy of dial calibration

0.5% from 21 kc to 47 Mc

1.5% from 10 kc to 110 Mc

Interpolation dial

100 divisions

Stability

About 0.2% total drift during the warm-up period within the frequency range 21 kc to 47 Mc. Drift is essentially completed within 1 hour.

CARRIER OUTPUT

Output level

- (1) 0.2 μ V to 0.2 V open-circuit from the attenuator outputs. The level is adjustable in steps of 2 dB by means of the cascaded 10 x 2 dB and 4 x 20 dB resistive attenuators, and continuously by means of the carrier control. In the 47 - 110 Mc range, the maximum obtainable level may fall to 0.1 volt.

The attenuators are calibrated in μ V and dB over 1 μ V open-circuit.

- (2) 0.2 - 2 volts open-circuit from separate 0.2 - 2 V output. In the 47 - 110 Mc range the maximum output may fall to 1 volt.
- (3) Up to 130 V continuously adjustable from the 0.2 - 2 V output, if the inductive source impedance is resonated by means of an ex-

ternal capacitor. The maximum available power is about 0.5 watt into a 5-kilohm load.

Output impedance

- (1) Attenuator outputs: 10 ohms and 75 ohms. In the 20-200 millivolt range the impedance is 13 ohms higher.

A 10/50 ohm version can be supplied on request.

- (2) 0.2 - 2 V output: 200 ohms source impedance when the attenuators are connected.

Accuracy of output voltage

The accuracy at 2 volts output is

0.2 dB up to 10 Mc

0.5 dB above 10 Mc

The accuracy of the attenuator outputs is the sum of the 2-volt output accuracy and the attenuator accuracies stated below:

Attenuator accuracy:

0.5 dB + 0.2 μ V up to 10 Mc

1 dB + 0.5 μ V up to 30 Mc and at levels below 20 mV

3 dB + 1 μ V up to 110 Mc and at levels below 20 mV

Frequency response

The change in carrier level without resetting of the carrier control is typically:

± 1 dB from 10 kc to 22 Mc

± 2 dB from 21 Mc to 47 Mc

± 3 dB from 46 Mc to 110 Mc

Distortion of carrier

The total harmonic distortion is about 7%. No subharmonics.

Stray radiation

Measurements down to the lowest levels are possible because of careful shielding of all RF units.

Terminals

All RF outputs furnished with UHF type SO 239 coaxial sockets.

AMPLITUDE MODULATION

Modulation depth

0 to 100%

The meter scale is calibrated in %AM from 0 to 90.

Distortion

The envelope distortion is typically

0.5% at 30% AM

1.5% at 80% AM

5% at 90% AM

The limit values are

1.5% distortion at 30% AM

3% distortion at 80% AM

No side-band cutting

Accuracy of AM

The actual AM at 400 cps may differ up to 5% of reading + 1% AM from the value indicated by the meter at frequencies up to 30 Mc and 10% of reading + 1% AM up to 50 Mc.

Internal modulating oscillator

Frequency: 400 cps $\pm 2\%$

Distortion: below 0.3%

Incidental frequency modulation

Less than 30 parts per million at frequencies below 30 Mc with 30% AM, 400 cps.

Residual AM

The carrier noise level without modulation is equivalent to 0.1% AM.

External modulation

About 11 volts into a load of 5 kilohms required for 90% AM at 1 kc. The modulation depth is controlled and indicated in the same manner as internal AM.

The frequency response, referred to 400 cps, is within ± 1 dB from 20 cps to 10 kc. These limits apply to carrier frequencies above 200 kc, at lower frequencies the highest allowable modulation frequency is reduced.

AF in the carrier output

With a modulating frequency of 400 cps and 30% AM, the AF component in the output varies typically from 26 dB below the carrier level at a carrier frequency of 10 kc to 46 dB below at all carrier frequencies above 4.6 Mc. At other modulation frequencies and depths it is proportionally lower or higher.

AF output

A synchronizing voltage of maximum 12 volts from a maximum 2.5 kilohm source impedance is available at the AF binding posts.

POWER SUPPLY

Voltages: 110, 115, 127, 200, 220, and 240 volts.

Line frequencies: 50 to 60 cps.

Consumption: 65 watts

TUBES

1 EAA91 (6AL5)	1 EC81 (6R4)
1 ECC81 (12AT7)	1 PCF80 (8A8)
2 PL81 (21A6)	1 85A2 (5651)

MOUNTING AND FINISH

Steel cabinet finished in grey enamel

OVERALL DIMENSIONS

Height	Width	Depth
380	565	295 mm
15	22 1/4	11 1/2 inches

The front panel is compatible with a 19-inch standard rack.

WEIGHT

25 kilos net (55 lbs)

ACCESSORIES SUPPLIED

1 type 3A3 coaxial cable (75 ohms) with type PL-259 plugs.

1 type 12G19 - 1.5 power cord

1 type 465-A5 screening cap for 2-volt output.

SECTION 1 GENERAL DESCRIPTION

1.1 OPERATING PRINCIPLE

The Signal Generator consists of an unmodulated radio-frequency oscillator followed by an aperiodic modulating stage feeding two attenuators connected in cascade. The input voltage of the attenuators is measured by means of a diode voltmeter.

The modulation can be accomplished either by means of a 400-cps built-in oscillator or by means of an external tone generator. The meter can be switched over to measure the percentage modulation.

The power supply is electronically regulated.

1.2 THE RADIO FREQUENCY OSCILLATOR

The oscillator (tube No. 1) is operated as a Collpit oscillator with a split-stator tuning condenser having silver-plated brass plates and carefully made ball bearings in order to avoid back-lash. The total range from 10 kc to 110 Mc is covered in 12 sub-ranges, each decade having 3 ranges. The frequency dial is individually engraved in the 3 ranges from 210 kc to 2.2 Mc, and the accuracy is about 0.2% in these 3 ranges after the warm-up period. Outside the 0.21-2.2 Mc range the accuracy is better than 0.5% except for the first and the last range where the accuracy is about 1.5%. The 12 coils are mounted in a coil turret and all of them can easily be removed by pressing outwards the appropriate "spoke" of the bronze wheel so that the stamping with the coil snaps out of the slot in the aluminum wheel.

The frequency dial has a coarse tuning knob and a fine tuning knob with a dial with 100 divisions. The friction drive used for the fine tuning is provided with ground driving wheels and accurate bearings providing for a very constant gearing and minimum backlash.

The RF voltage fed to the modulating stage is fairly constant through the ranges and generally it varies only about ± 1 dB with the exception of the two ranges from 21 to 110 Mc. The frequency drift during the warm-up period depends somewhat on the frequency and is about 0.2%. The drift is essentially completed in the first hour. On the first range from 10 kc to 22 kc and on the last range, the drift is somewhat greater.

1.3 THE MODULATING AMPLIFIER

consists of an output penthode operating with grid modulation. Both the RF and the AF signals are fed to the grid. The RF components of the anode current are stopped by an anode choke and fed to the 2 dB step-attenuator. The choke is switched simultaneously with the coils of the oscillator in order to operate the modulating tube with an anode impedance as small as possible. By this means the inevitable AF output voltage from the modulating oscillator is kept at a minimum. Nevertheless the modulation trapezium viewed on the cathode ray tube of an oscilloscope will look distorted unless the RF frequency is very much higher than the modulating frequency or unless the small residual super-imposed AF voltage is filtered out by means of a high-pass filter inserted between the signal generator and the oscilloscope. In fact the envelope distortion is completely independent of the superimposed AF voltage, and this voltage will in most cases be of no importance.

The envelope distortion is to some extent dependent on the modulating tube, but almost all tubes give a distortion of less than 3% at 80% modulation and generally there is no difficulty in finding a tube giving only about 1.5% distortion at 80% modulation with 1 kc. At 30% modulation the distortion is then about 0.3% and at 90% modulation somewhere between 2 and 5%. If the modulation percentage is so defined that the energy contained in the side bands is measured in proportion to the energy in the carrier instead of comparing the amplitudes, 100% modulation is obtainable by setting the meter to the last line on the scale. The distortion at 1 kc is generally less than 5% but it will rise

in the case of over-modulation. The hum modulation is less than 0.1%. Owing to the aperiodical modulation there is no side-band clipping.

The modulation can be accomplished either by means of the built-in 400 cycle oscillator or by means of an external AF generator connected to the AF terminals. The input impedance is about 10 k Ω , and about 4 volts are required for 30% modulation. The modulation characteristic is flat within 1 dB from 20 cps to 10 kc at carrier frequencies higher than 200 kc. The modulation percentage is read on the built-in meter with the meter switch in position MOD. The accuracy is about 5%.

The modulation percentage is independent of the setting of the carrier output. The very loose coupling between the modulating tube and the RF oscillator provides for the very low frequency modulation of 30 cycles per megacycle at 30% - 400 cps - modulation at frequencies below 30 Mc. At higher frequencies, the frequency modulation is, rather, dependent on the frequency, because the input impedance of the modulating tube varies a good deal and because the coupling between the two tubes in question is tighter. FM values between 0.5 kc and 30 kc are possible. Due to the square law $i_a - V_g$ characteristic of the modulating tube the RF output will have a second harmonic of about 7% with 2 volts at the attenuator. The distortion is proportional to the output voltage from the modulating tube at high output level.

1.4 THE MODULATION OSCILLATOR

is an L-C oscillator operating on 400 cps, followed by a cathode follower. The accuracy is 2%, and the distortion is less than 0.3%—generally only about 0.1%. The hum is less than 0.05%—generally about 0.03%. Thus it is possible to take advantage of the low modulation distortion of the output tube also with the built-in 400 cycle oscillator used for modulation.

The oscillator operates by means of a double triode, No. 5. The modulation takes place when the switch MODULATION is set to one of the positions INT. MOD. or 400 cps OUTPUT. The modulating voltage fed to the grid of the modulating tube is controlled by means of the knob MODULATION. The voltage is also present at the AF terminals when the switch MODULATION is set to position 400 cps OUTPUT. The maximum output voltage is about 12 volts. The output impedance is dependent on the setting of the knob and varies between 0 and about

2.5 k Ω with the knob in its mid-position. The output current drawn must not exceed one milliamp, otherwise the distortion will rise severely.

1.5 THE ATTENUATOR SYSTEM

The output voltage from the modulating tube is fed to a three-position switch. With the switch in position ATT., the voltage is only present at the output jacks at the right-hand corner of the generator. With the switch in its mid-position, the voltage is also present at the jack "RF 0.2-2 V EMF" and at this jack the maximum output voltage is had with the switch in position "Vmax". Two attenuators in cascade provide for an output voltage which can be set to any value between 2 μ V and 200 mV in 2 dB steps with full deflection of the voltmeter. Voltages between 0.2 μ V and 2 μ V can be had if the input at the attenuator is reduced correspondingly.

If the μ V reading of the 2 dB step attenuator is multiplied by the factor reading of the 20 dB step attenuator, the output voltage is had in microvolts emf, provided that the meter reads 2 volts.

If the dB readings of the two attenuators and the meter are added up, the output level is had in dB over 1 μ V.

With the output switch set to position ATT., an input voltage of 2 volts to the attenuator is obtainable in the range from 10 kc to 46 Mc, and 1 volt in the highest frequency range.

The output impedance at one RF jack is 10 ohms for all positions of the 20 db step attenuator except for the x10,000 position where it is 23 ohms. At the other RF jack (immediately below) the impedance is 65 ohms higher, thus providing for correct termination of the 75-ohm cable.

The output impedance at the "0.2-2 V RF" jack is about 200 ohms. The output impedance is ostensibly zero, if the output meter is used for setting the output voltage to a preselected level to be maintained irrespective of variations in the load. With the output switch in position "Vmax", the attenuator is disconnected, and a maximum output current of 14-20 milliamps can be drawn when the output is short-circuited. The output impedance is dependent on the RF range chosen and it consists of the self-induction of the anode choke of the output

tube in parallel with the capacity of the anode and all the components and the load connected to it. Output voltages of 100 volts or more can be had if the resonance frequency of the output circuit is in resonance with the oscillator, and the ohmic component of the load is 20 k Ω or more. Outputs between 0.2 and 0.7 watt to a 5-k Ω load are generally obtainable in the range 10 kc to 1 Mc, when tuning the output circuit to resonance with an external variable condenser.

The accuracy of the output voltage at the "0.2-2 V" jack is ± 0.2 db at frequencies below 12 Mc. With correct termination: 0.5 dB at 50 Mc and about 1.5 dB at 100 Mc with maximum obtainable deflection of the meter.

The accuracy of the attenuator is ± 0.5 dB ± 0.2 μ V at frequencies below 10 Mc and about ± 1 dB ± 0.5 μ V up to 30 Mc. On the highest frequency range: about 3 dB ± 1 μ V at levels below 20 mV.

Note: The resistors of the 20 dB step-attenuator are rated for 0.1 watt and they will therefore only stand a current of about 0.1 amp. The attenuator should therefore never be exposed to voltages higher than 1 volt.

1.6 THE VACUUM-TUBE VOLTMETER

operates with a double diode. One diode is used as rectifier and the other is used for compensating the initial current of the rectifying diode. The meter is connected directly to the diode through the variable resistor ADJ 2, which provides for calibration of the sensitivity. The zero setting resistor ADJ 1 is accessible through a hole in the front panel, but once set it will not be necessary to use it often. The diode introduces some distortion of the output voltage, but it reduces the second harmonic originating from the output tube so much that the resulting distortion is not greater with the diode than without.

The voltmeter measures the input voltage of the attenuator system and the voltage at the "0.2-2 V" jack, if this jack is connected to the attenuator by setting the output switch to position "2 V."

The dial of the meter is provided with a division for every 0.1 volt on the range 0.1 to 2 volts. The 2-volt division has to be used in order to make the attenuator dials direct reading. There is a dB scale below

the volt scale. Together with the dB figures of the attenuator dials it gives the output level in dB over 1 μ V. Output voltages within the 2 dB steps of the attenuator can be read from the upper scale with an almost maximum reading accuracy because only the upper end of the scale should be used.

While adjusting the carrier, the modulation must be switched off if the modulation percentage exceeds 30% or if the modulation frequency exceeds 1 kc, otherwise there is a risk of getting wrong indications due to the a-f voltage present at the diode.

1.7 THE MODULATION METER

The meter is switched to measure the modulation percentage when the METER switch is set to position MOD.

The a-f voltage fed to the grid of the modulating tube is measured by means of 2 Germanium diodes as rectifiers. The rectified voltage is fed to the meter through the variable internal resistor ADJ 4-"Calibration of M% Meter."

The frequency range is 30-15,000 cycles and the accuracy of indication is 5% at modulation percentages higher than 30 with carrier below 46 Mc.

1.8 THE POWER SUPPLY

is electronically regulated with tube No. 6 operating as series tube and the penthode section of tube No. 4 operating as amplifier. The bridge connected selenium rectifiers are so rated that a life exceeding 50,000 hours may be expected.

The regulated output voltage is 160 volts, and all tubes except the anode of No. 5B are operated at that voltage.

The instrument operates from a 50-60 cps power line and can be adjusted to the following voltages: 110, 115, 127, 200, 220, and 240 volts. The line fuse is mounted on the front panel together with the line voltage switch.

The consumption is about 65 watts.

1-9 EXTRA ACCESSORIES

The type SP15 Voltage Divider provides for 40 dB attenuation when connected to a signal generator with 50 Ω output impedance.

The voltage divider consists of a 49 Ω resistor in series with a 1 Ω resistor across which the output voltage is present. The 1 Ω resistor is of the disk type with negligible self induction providing for a uniform frequency response. The etched cover plate of the small cast box containing the resistors carries the circuit diagram. The two jacks of the box fit the PL259 plug of the cable supplied with the generator.

The type KA15 Dummy Antenna complies with the 1948 standards of the Institute of Radio Engineers. The etched cover of the small cast box containing the components carries the circuit diagram. The Dummy Antenna is connected to the signal generator by means of the cable supplied.

Use the 10 Ω jack at frequencies up to about 4 Mc. At higher frequencies use the 75 Ω jack.

The type TL15 Test Loop complies with the 1948 standards of the Institute of Radio Engineers.

The Loop is 0.25 m in diameter and consists of a three-turn winding in a copper tubing for electrostatic shielding. A 403 Ω resistor is connected in series with the winding and mounted in a small housing at the base of the loop. The resistance is proportioned to make the field strength in volts per meter at an arbitrary distance of 0.6 m (24 inches) equal to one tenth of the signal generator reading in volts. The transmitting loop is to be connected to the 10 Ω jack of the signal generator. The loop current will be approximately uniform up to about 20 Mc with a cable length of about 1.2 m.

SECTION II OPERATING INSTRUCTIONS

2.1 CONNECTION

Before switching on the instrument, make sure that the power line switch on the front panel has been set to the correct position, and that the correct fuse is mounted. The switch has the following positions: 110, 115, 127, 200, 220, and 240 volts.

The instrument is switched on with the power switch OFF ON and should be allowed to warm up for a few minutes.

2.2 CONTROLS, DIALS, AND TERMINALS

(a) Frequency controls

The main tuning dial has 3 engravings covering one decade. The frequency is read either directly in kc or Mc or is had after multiplying the reading with 10, depending on the setting of the range switch.

The range switch has 12 positions and covers the range from 10 kc to 110 Mc.

The main dial can be turned either by means of the big knob mounted on it or by means of the fine tuning knob through a friction drive.

The dial of the fine tuning knob has 100 divisions, and each division represents a detuning of max. 0.1%.

(b) Output controls

The output level is set by means of the two attenuators and the knob CARRIER. The attenuators are direct reading in microvolts when the CARRIER is so set that the meter reads 2 volts. The output level in dB over 1 μ V is had by adding up the dB readings of the attenuators and the meter.

(c) Modulation controls

The switch MODULATION allows the signal generator to be modulated either by means of the built-in 400 cycle generator or by means of an external generator operating in the range 30-15,000 cps.

The modulation percentage is read on the meter with the METER switch in position MOD. and the modulation percentage is controlled by means of the knob MODULATION.

(d) Terminals

The power input terminals provide for connecting to the jack connector of the type 12G19 - 1.5 power cord that is supplied with the Signal Generator.

The RF output terminals fit the American type UHF connector No. PL259. A 1 m long type C3A3 output cable provided with a UHF connector at both ends and having a characteristic impedance of 75 Ω is supplied with the instrument.

The AF terminals are used for connecting the external audio frequency generator to the signal generator. The input impedance is 10 k Ω , and about 10 volts are required for 90% modulation.

With the MODULATION switch in its mid-position, the 400 cycle modulating voltage from the built-in generator is available across the AF terminals. The output voltage depends on the setting of the knob MODULATION.

2.3 STEP-BY-STEP OPERATION

- (1) Set the line voltage selector to the voltage on which the instrument is to operate.
- (2) Connect the instrument to the power line, switch it on, and allow it to warm up for some minutes.
- (3) Set the METER switch to its mid-position and check the mechanical zero of the meter.
- (4) Set the METER switch to position CARRIER and the knob CARRIER to zero. Adjust the VTVM ZERO potentiometer by means of a screw driver (at least 100 mm, 4 inches, long) so that the meter reads zero again.

- (5) Set the RANGE switch knob to the appropriate range in order to obtain the desired output frequency, and set the main dial to that frequency. Use the illuminated index.
- (6) Set the knob CARRIER so that the meter reads 2 volts with the RF output switch at position ATT.

Only 1 volt is guaranteed on the range 46-110 Mc.

- (7) Set the MODULATION switch to position INT. or 400 cps OUTPUT in the case of internal modulation, or to position EXT. in the case of modulation from an external generator. Connect the external generator to the terminals AF. Do not use position 400 cps OUTPUT with an external generator connected in the case of external modulation.
- (8) Set the METER switch to position MOD. and rotate the knob MODULATION until the meter reads the percentage required.
- (9) Connect the load to the 10 ohm RF jack when operating at low radio frequencies (10 kc to about 5 Mc) thus avoiding calculations if the impedance of the load is greater than 200 ohms. Use the 75 ohm jack and the 75 ohm cable at higher frequencies and terminate the cable in a 75 ohm resistor in order to avoid reflections. The voltage at the terminating resistor will then be half the emf output voltage read on the attenuator dials.

Connect the load to the "0.2-2 V" jack if a voltage within this interval is required, and set the output switch to 2 V. Terminate the 75 Ω cable in a 75 Ω resistor in order to avoid reflections at frequencies higher than 5 Mc. The voltage read on the meter will then be present at the end of the cable, but it is reduced to about 0.5 volt. If somewhat higher distortion of the output voltage can be tolerated, about 1 volt unmodulated is obtainable in the major part of the frequency range.

Set the RF output switch to position Vmax if a voltage higher than 2 volts or the maximum current obtainable is required. The meter has now been disconnected and the voltage at the load has to be measured with an external voltmeter. The maximum output voltage obtainable depends on the load and amounts to about 120 volts, if the output circuit is in resonance with the oscillator frequency.

SECTION III

MAINTENANCE

3-1 GENERAL

The type MS111 Signal Generator is of a sturdy design and will offer long troublefree service, if only the following precautions are taken:

The instrument should be protected against excessive moisture and, when operating, against elevated temperatures. To ensure free circulation of air the instrument must rest on its rubber feet, not directly on the bottom, and the top louvres must not be covered with papers or the like.

3-2 REMOVING THE INSTRUMENT FROM THE CABINET

The instrument can easily be removed when the four fixing screws along the edge of the front panel have been removed.

3-3 TUBE REPLACEMENT

It is generally not necessary to replace the tubes until they give rise to some kind of trouble, such as: no or insufficient output, no or faulty modulation, abnormal dependence on line voltage, etc.

Tube No. 1 is a type EC81 or 6R4 operating as RF oscillator. The tube is placed inside the oscillator box, which is taken apart by loosening all the screws pressing the big part of the box between the two lids (one lid is placed inside the other) and pulling out the big part. Replacement of the tube may sometimes involve an adjustment of the trimmers. The trimming, however, should not be made until the generator has been switched on for some hours.

All faultless specimens can be used.

Tube No. 2 is a type PL81 or 21A6 operating as modulator with grid modulation. Almost all specimens can be used and about half of a batch of tubes without making any adjustments. As the envelope distortion is dependent on the tube, this distortion should always be checked after a tube replacement. This is readily done by measuring separately the

side bands arising by the modulation by means of the type FRA2 Radiometer Wave Analyzer, which is a very selective superheterodyne receiver with double conversion. As the first intermediate frequency is 60 kc and the first oscillator operates on the range 60 kc to 44 kc, the two measuring ranges from 0-16 kc and from 120-104 kc are covered. By setting the dial to 3 kc the instrument also becomes sensitive to 117 kc, and if the Standard Signal Generator operates at this frequency and e.g. is modulated with 400 cps, the carrier is found on the dial at 3 kc and the desired side bands of first order at 3.4 kc and 2.6 kc. The side bands which are due to the distortion of the modulation are located at 3.8 kc - 4.2 kc - 4.6 kc and so on, and are symmetrical with respect to 3 kc. The side bands due to hum are located at 3050 - 3100 - 3150 and so on, and are measured with the 2 cps band-width of the Wave Analyzer.

The cathode of tube No. 2 operates on about 18 volts, and the anode and screen grid on about 160 volts. If it is impossible to find a tube with about 1.5% distortion at 80% modulation with 400 cps, it may be an improvement to alter the 22 ohm unsurpassed part of the cathode resistor somewhat.

Tube No. 3 is a type EAA91 or 6AL5 double diode which can be replaced right away. After the replacement set the zero, check the sensitivity and correct the setting of the potentiometer ADJ 2 - CAL OF VTVM, if required. The check is easily made by measuring e.g., a 100 kc unmodulated output voltage of 2 volts at the 2 V jack with an external voltmeter which measures rms values or mean values and which has an input impedance of some kilohms in order not to increase the distortion from the output tube.

Tube No. 4 is a type PCF80 or 8A8. The penthode section of the tube is used as amplifier of the electronically regulated power-supply. Check the hum of the 160 volt output from the regulated power-supply after replacement. The hum should be less than 2 millivolts. A normal tube gives a reduction of the 100 cps hum at the anode of tube No. 6 of about 37 dB or 70 times. The 50 cps and 150 cps hum is generally 10 to 20 dB lower than the 100 cps hum. If the hum is not measured with a Wave Analyzer but with an ordinary vacuum-tube millivoltmeter, it is necessary to stop modulation, e.g., by setting the

switch MODULATION to position EXT. At 90% modulation with 400 cps, a 400-cps voltage of about 50 millivolts is present at the 160-volt terminal and about 0.5 volt at the 260-volt terminal.

Tube No. 5 is a type ECC81 or 12AT7 operating as 400-cps oscillator. The d-c voltages at the cathodes are about 16 and 65 volts, respectively, and the 400-cps voltages about 14 and 16 volts, respectively. At the anode of the oscillator tube there is about 55 volts 400 cps. Make sure that the distortion is sufficiently low after replacement of the tube. Adjust the variable resistor SET TO MIN. DIST. AT 1V AF OUTPUT in the cathode lead of the oscillator triode, if necessary. Tubes No. 4 and 5 can generally be replaced without any change in distortion. The distortion will rise only if the tubes are defective in some respect.

Tube No. 6 is a type PL81 or 21A6 operating as series tube in the electronically regulated power supply.

The voltage at the anode is about 250 volts. At the cathode it is about 160 volts. The 100-cps hum at the anode is about 140 millivolts and about 2 millivolts at the cathode.

The grid is about 7 volts negative referred to the cathode at nominal line voltage with the carrier control so set that the drain from the power supply is heaviest. With 10% lower line voltage the cathode-grid voltage is about minus 2.5 volts. If this voltage is about minus 1 volt, the tube is probably worn out and must be replaced.

Tube No. 7 is a type 85A2 or 5651 voltage reference tube which can be replaced right away.

