A TWO-WAY RADIO COMMUNICATIONS TRAINING PROGRAM

LESSON INDEX

Lesson Index

MOTOROLA TRAINING INSTITUTE

38 LESSONS

RECEIVERS

What is frequency modulation?
FM communications receiver—block diagram analysis.
The RF amplifier.
The high frequency oscillator—mixer and first IF amplifier.
The second mixer, oscillator and IF stages.
The limiter.
The discriminator.
Squelch and audio circuits.
The meter in the communications receiver.
Receiver specifications.

TRANSMITTERS—POWER SUPPLIES—ANTENNAS

FM transmitter block diagram analysis.
Transmitter oscillator.
The phase modulator.
The audio circuit; deviation control.
Frequency multiplication.
Power amplifier.
The meter in the transmitter.
Transmitter specifications.
Power supplies—general.
Vibrator and dynamotor supplies.
Transistor switch and AC power supplies.
Antennas and transmission lines.

SERVICING AND SPECIAL EQUIPMENT

"Private-Line" systems.
Selective signaling equipment.
Test sets.
General trouble shooting.
Receiver servicing.
Transmitter servicing.
Test equipment.
Installations and preventive maintenance.

TRANSISTORS

Semiconductor materials.
Germanium and silicon diodes.
The transistor.
Transistor amplifiers.
Transistor bias—DC stability.
Transistorized audio equipment.
Transistorized receiver circuits.
Servicing transistorized equipment.

trol. The Phase Modulator. Frequency Multiplication. Power Amplifier. Antenna Circuit.

LESSON T-2, THE TRANSMITTER OSCILLATOR:
Frequency Stability. Power Requirements. The Oscillator Load. Operating Frequency. High Band Oscillator. Low Band Oscillator. Offset Oscillator. Transmitter VCO.

LESSON T-3, THE PHASE MODULATOR
PM Versus FM. Vectors. Rate Of Change. Phase Modulator. Preemphasis. Serrasoid Modulator. Direct FM. Sidebands And Bandwidth.

LESSON T-4, AUDIO CIRCUIT
Deviation Control. Microphones. Preemphasis. Audio Preparation. Clippers. Integration. Splatter. Deviation Control Circuits. Direct FM Audio Circuits.

LESSON T-5, FREQUENCY MULTIPLICATION
Class C Multipliers. Multiplier Operation. Flywheel Effect. Tank Circuit Impedance. Driving Power. Tube Muliplers. Deviation Multiplication. Transistor Multipliers. Varactor Circuit.

LESSON T-6, THE POWER AMPLIFIER
FM Power Amplifiers. Drive and Bias. PA Input Circuits. The Output Tank. Antenna Coupling Circuits. Impedance And Power Transfer. Spurious Emissions And Harmonics. Feedback And Neutralization. Ferrite Devices. PA Circuits. Protective Circuits.

LESSON T-7, METERING THE TRANSMITTER
Transistor Transmitters. PA Position. Loading The Antenna. Neutralization. Frequency Adjustment. Deviation Adjustment. Troubleshooting.

LESSON T-8, TRANSMITTER SPECIFICATIONS
Frequency Range And Separation. Frequency Stability. Power Requirements. RF Power. Spurious Outputs. Sideband Noise. Audio Impedance. Audio Sensitivity And Response. Environmental.

LESSON T-9, PORTABLE POWER SUPPLIES
Batteries and Battery Life. Nickel-Cadmium Battery. Charging Ni-Cads. AC Power Supplies. Battery Chargers. Voltage Regulation. Zener Regulators. Current Regulator Sensors. Temperature Sensors.

LESSON T-10, MOBILE POWER SUPPLIES
The Vibrator. The Dynamotor. Transistor Power Supplies. DC Distribution And Logic. Ground Reversing Converters. Protection Circuits.

LESSON T-11, AC POWER SUPPLIES
Series-Pass Regulators. Switching Regulators. Hybrid Power Supply. Phase-Controlled Power Supply. Pulse-Width Regulated Power Supply.

LESSON T-12, ANTENNAS AND TRANSMISSION LINES
Radio Waves. Wave Motion And Polarization. Wavelength. Radiation Pattern. Ground Waves and Sky Waves. Basic Antenna Action. Antenna Impedance. Gain And Directivity. Patterns And Coverage. Antenna Types. Transmission Lines. Standing Waves.

REFERENCE TEXT 3-T, LOGIC FUNDAMENTALS
Transistor Switch Characteristics. Fundamentals Of Logic. Transistor Switches. Transistor Multivibrator Circuits. Logic. Inhibitor & Gating Functions. Logic Representations. Servicing Of Logic Circuits. Symbolic Logic. Logic - What Is It? Logic Levels. Logic Symbols And Circuits. Logic Support Functions. Input/Output Languages.

REFERENCE TEXT, BASIC THEORY & APPLICATION OF TRANSISTORS
Structure Of Matter, Crystals, Acceptors And Holes, PN Junctions. Transistors. Transistor Amplifier Fundamentals. Parameters, Equivalent Circuits. Bias Stabilization. Characteristics Curves And Charts. Audio Amplifiers. Phase Inverters. Power Amplifiers. Complementary Symmetry. Compound-Connected Transistors. Tuned Amplifiers. Coupling Networks. Neutralization And Unilateralization. Wide-Band Amplifiers. Oscillators. Pulse And Switching Circuits. Modulation, Mixing And Demodulation.

REFERENCE TEXT, SELECTIVE CAVITIES
What It Is. Selectivity. How To Get Selectivity. Power. Coupling Loops. Stability. Installation And Tuning.

LESSON M-1, TONE SQUELCH
Frequency-Sensitive Elements. Reed Operation. Bandwidth And Drive. Operating Principles. Encoder Circuits. Decoder Circuits. Dual Purpose Units. Multi-Tone Systems. Switching By Tone.

LESSON M-2, SELECTIVE SIGNALING
Signaling Methods. One-Tone Systems. Two Sequential Tones. Two Simultaneous Tones. Three Tones. Four Tones. Five Tones. Maintenance.

LESSON M-3, THE TEST SET
Test Set Functions. Controls. Meter Scales. AC Voltmeter. Crystal Oscillator. Peaking Generator. Deviation Meter. Simplified Circuits. "MICOR" Metering.

LESSON M-4, GENERAL TROUBLESHOOTING
Isolating Defective Units. Check Of Individual Units. Locating The Defective Part. Techniques. The Voltmeter. Voltmeter Tips. Voltmeter Characteristics. Resistance Testing.

LESSON M-5, RECEIVER SERVICING
Techniques. Troubleshooting Char Signal Substitution. Alignment. Sen tivity Check. Stage Gain Measu ments.

LESSON M-6, TRANSMITTER SERVICING
Preliminary Considerations. Met ing. Symptom Analysis. Audio S tion. Troubleshooting Chart. Trout Isolation. Parts Replacement.

LESSON M-7, TEST EQUIPMENT
Accuracy. Time Base Accuracy. F quency Resolution. Techniques. F quency Meters. Heterodyning. Cou ers. Comparison Receivers. Deviati Monitors. Signal Generators. Wa meters.

LESSON M-8, INSTALLATIONS AN PREVENTIVE MAINTENANCE
Preinstallation Checks. Mobile Insta ations. Base Station Installation Noise Suppression. Preventive Mai tenance. Power Sources. Antenna Towers. Receivers. Transmitters.

REFERENCE TEXT, DUPLEXERS
The Simplex System. The Dupl System. Need For Isolation. Receiv Selectivity & Desensing. Transmitt Noise. Isolation Between Trans. Rec. How To Get Isolation. Horizont Antenna Separation. Vertical Antenn Separation. Advantages Of A Duple er. Things Duplexers Must Do. Loss Through The Duplexer. The Bandpa Duplexer. The Band-Reject Duplexe Other Types Of Duplexers. Use Duplexers. Use Of Duplexers Combiners.

REFERENCE TEXT 4-T, ANTENNA AND LINES
Antenna System Concepts. Antenn Characteristics. Mounting & Phasir Arrays. Side-Mounted Antenna Troubleshooting Antennas. Groun Wave Propogation. Direct-Wave Con ponent. Ground-Reflected Compo ent. Surface-Wave Component. Tro ospheric-Wave Component. Abnorm Effects Of Troposphere. Half Ar Quarter-Wave Antennas. Voltage Ar Electric Field. Current And Magnet Field. Standing Waves. Velocity Propogation. Resonance, Resistance Impedance. Transmission Lines. Bas Radiation Patterns. Dipole Radiation

REFERENCE TEXT, TRANSMISSION LINES
Solid Air And Foam Dielectric Electrical Properties. Impedance An Velocity. Environmental Considera tions. Connectors. Installation An PM. VSWR.

REFERENCE TEXT, BASE STATIO ANTENNAS
What Is An Antenna? Matching An VSWR. Half-Wave Dipole. Polarit And Patterns. Gain. Side-Mounte Antennas. Noise. Bandwidth.

LESSON A-1 SEMICONDUCTOR REVIEW
Semiconductor Materials. Carriers. Hole Movement. PN Junctions. Diodes. Zener Diodes. Varactors. SCR's. Special Purpose Diodes. Diode Identification. Diode Testing.

LESSON A-2 TRANSISTOR REVIEW
Bipolar Transistors. Transistor Elements. Operation. Transistor Currents. Transistor Amplifiers. Impedances. Coupling. Bias Circuits. Thermal Stabilization.

LESSON A-3 FET REVIEW
FET Construction. Operation. Junction FET. Depletion IGFET. Enhancement IGFET. Dual Gate FET. Vertical FET. Symbols. FET Amplifiers. Constant Current Diodes. FET Servicing. Handling FETS

LESSON A-4 INTEGRATED CIRCUITS
Types. Packaging. IC Symbols. Linear IC's. Differential Amplifiers. Operational Amplifiers. CMOS IC's. Handling CMOS Devices. Servicing IC's.

REFERENCE TEXT 1-S, TRANSISTORS
Transistor Theory. Operation Of The Diode. Operation Of The Transistor. Typical Operating Characteristics. Typical Transistor Ratings. Applications In Two-Way Equipment. Servicing Transistorized Equipment.

REFERENCE TEXT — TRANSISTOR FUNDAMENTALS
System Considerations. Transistor As An Active Device. Semiconductor Physics. P-N Junction. How Transistors Operate. Basic Circuit Configurations. Circuit Configurations. Characteristic Curves. Operating Limits. Power Dissipation. Transistor Amplifier Circuits. Classes Of Amplifiers. Coupling Networks. Transistor Oscillator Circuits. LC Oscillators. Crystal-Controlled Oscillators. RC Oscillators. Relaxation Oscillators. Zener Diodes. Silicon Controlled Rectifiers. Unijunction Transistors. Field-Effect Transistors.

LESSON R-1, FREQUENCY MODULATION
Amplitude Modulation. The FM Transmitter. Amount Of Frequency Change. Rate Of Frequency Change. Center Frequency. Deviation. The FM Receiver and Detection. Audio Frequency. FM Is More Interference-Free. FM Transmitter Efficiency. FM Bandwidth.

LESSON R-2 RECEIVER BLOCK DIAGRAM ANALYSIS
Receiver Requirements. Simple Broadcast Receiver. Basic FM Receiver. Communications Receivers. Two-Way Bands. The Double Superhet. Triple Conversion. Single Conversion Receivers. Mulitiple Frequency Operation: Integrated Circuits.

LESSON R-3, RF SECTION
Single-To-Noise Ratio. Man-Made Noise. Natural Noise. Receiver Noise. Transistor And Tube Noise. Selectivity. Desensitization. Intermodulation. Preventing Desensitization And IM.

LESSON R-4, OSCILLATOR MIXER AND IF
High Frequency Oscillator. Crystals. Vibrational Modes. Crystal Aging. Temperature Considerations. Crystal Warping. Frequency Multipliers. Tube Mixer. Bipolar Transistor Mixer. FET Mixer. Deviation. The First IF Amplifier. Crystal Filters.

LESSON R-5, SECOND MIXER AND IF SECTION
The Second Oscillator. Tube Oscillator. Transistor Oscillators. The Second Mixer. Tube Mixer. Solid State Mixers. Selectivity. IF Stage. Single Conversion Receiver. Mixer. "Pulsar" IF Board. The "MICOR" IF.

LESSON R-6, THE LIMITER
Limiter Action. The Saturated Limiter. The Tube Limiter. Transistor Limiter. Automatic Bias Operation. Saturation And Noise Reduction. The Limiter Output. Flywheel Effect. Receiver Quieting.

LESSON R-7, THE DISCRIMINATOR
Plain Vector Talk. Basic Discriminator Action. Deviation Vs. Output. Phase Relationships. Modified Phase Detector. Crystal Discriminator. Deemphasis. Discriminator Response Curve.

LESSON R-8, SQUELCH AND AUDIO CIRCUITS
Tube Squelch. Transistor Squelch. Speakers. Tube Audio Section. Transistor Audio Circuits. "MOTRAC" Audio. "MOCOM 35" Audio. "Pulsar" Audio. "MICOR" Audio.

LESSON R-9, THE METER IN THE RECEIVER
Metering Methods. The Test Set. Metering Functions. Oscillator Metering. IF Metering. Discriminator Metering. Audio Metering. Voltage Readings. Troubleshooting. Decibels.

LESSON R-10, RECEIVER SPECIFICATIONS
General Specifications. Sensitivity. Desensitization. Selectivity. Measurement Methods. Modulation Acceptance. Intermodulation. Discriminator Stability. Oscillator Stability. Spurious Responses. Audio Output And Response.

REFERENCE TEXT 1-R, PRACTICAL GROUNDING
Grounding Principles. Grounding Practices. Resistance Measurements. Methods Of Improving Resistance. Driving Methods. Deep Grounding. Computed And Actual Resistances. Operating Results And Test Grounds. Copperweld Ground Rods.

REFERENCE TEXT 2-R, RF INTERFERENCE
Interference. Noise. Desensitizing. Spurious Responses. Intermodulation. Cavity Resonators. RFI Analysis Charts. Intermodulation Interference. Frequencies Of IM Products. IM In Transmitters. IM In Receivers. Diagnosis And Treatment. Sideband Noise Receiver Desensilization. Transmitter Noise. Receiver Problems.

REFERENCE TEXT 3-R IGNITION NOISE
Suppression Fundamentals. Preliminary Procedures. Locating The Sources Of Interference. Interference Suppression Techniques. Marine Radio Suppression. Shielded Ignition.

REFERENCE TEXT, LIGHTNING
Exposure Factors. Lightning Stroke Current. Incidence Of Thunderstorms. Cycle Of A Lightning Stroke. Introduction To Grounding. Grounding Philosophy. Equalization Of Potentials. Antennas And Supporting Structures. Two-Way Antennas. Microwave Antennas. Two-Way Antenna Structures. Microwave Antenna Structures.

LESSON T-1, FM TRANSMITTER BLOCK DIAGRAM:
Types Of Modulation. The Oscillator. The Audio Amplifier. Deviation Con-

NSTITUTE *course in* 2-way radio *includes:*

9 REFERENCE TEXT BOOKS

In addition to the 38 lessons, you will be supplied with reference texts—included with the training at no extra cost—to be used as supplementary reading and study material. The text books will be changed periodically so as to continually keep you supplied with the most up-to-date and suitable texts available.

Basic theory and application of transistors.
FM Transmission and Reception.
FM Transmitters and Receivers.
Pulse Techniques.
Antennas and Wave Propagation.
Handbook of Test Methods and Practices.
Electrical Fundamentals (DC)
Electrical Fundamentals (AC)
Theory and Application of Vacuum Tubes.

MORE THAN 20 ARTICLES

Also supplied are pertinent reprint technical papers and articles dealing with two-way radio systems, equipment, operation and maintenance.

HERE ARE A FEW TITLES:

Utilizing the new split-channel frequencies.
Communications antennas.
Suppression of ignition noise in mobile equipment.
System maintenance of two-way radio.
On locating intermittants.
Frequency modulation.
The split-channel story.

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A TWO-WAY RADIO COMMUNICATIONS TRAINING PROGRAM

LESSON MA-8
MAINTENANCE

Installations and Preventive Maintenance

MOTOROLA TRAINING INSTITUTE

A TWO-WAY RADIO COMMUNICATIONS TRAINING PROGRAM

LESSON MA-8
MAINTENANCE

Installations and Preventive Maintenance

—one of a series of lessons on two-way FM communications—

MOTOROLA TRAINING INSTITUTE
4501 W. AUGUSTA BLVD., CHICAGO 51, ILLINOIS
APPROVED BY THE STATE OF ILLINOIS
DEPT. OF REGISTRATION AND EDUCATION

PREFACE

This is one lesson of a complete Motorola Home-Study Course which presents to the Service Technician both the principles of operation and the maintenance of two-way FM radio systems. The program covers mobile, portable and base station equipment, including the latest transistorized units.

TWO WAY INSTALLATIONS AND PREVENTIVE MAINTENANCE

LESSON MA-8

TABLE OF CONTENTS

NOTICE

Diagrams and figures referenced in text are "fold-outs" in back of each lesson, for use while studying. The Examinations are also there.

You'll find two-way mobile radios installed in all types of vehicles--from the smallest foreign car to the largest earth-moving or machinery handling type of equipment.

TWO-WAY INSTALLATIONS AND PREVENTIVE MAINTENANCE

Lesson MA-8

Introduction

In this lesson we shall discuss the installation of two-way communications equipment. If the equipment is to continue to perform with maximum efficiency and reliability, it is essential for it to be properly installed and procedures must be followed to insure satisfactory operation of the equipment. A good installation also reduces the amount of future maintenance required on the system. In addition to installation techniques, we shall talk about the routine maintenance which must be practiced in order to assure continued good performance. Let us start our lesson by discussing the installation of a mobile two-way station.

Mobile Installations

After the equipment has been unpacked, inventoried, and inspected for possible damage, the complete installation must be planned. This will be governed by the car or vehicle in which it is to be installed. For our example we shall assume that a rear mount installation is to be made in a commercial car or cab. (It will have been previously determined whether the installation is to be a front mount or a rear mount.) The instruction manual must be studied carefully. Diagrams such as figure 1 and 2 are supplied to show the recommended location of the various units and their proper interconnections.

After the installation has been planned, the serviceman should proceed according to the suggestions in the manual. The housing for the receiver, transmitter and power supply is first installed. The drawer unit is removed and the housing located so that the drawer unit is accessible and can be readily removed for service. A minimum of 3 or 4 inches is required in front of the split-type housing--see figure 1. The housing must be well grounded to the car frame.

All paint and dirt must be scraped off and the surfaces burnished (with steel wool) to insure good contact. When mounting holes are being drilled, care must be taken to prevent the drill or mounting screws from coming too close to the gas tank or gas line.

The components inside the car may be mounted next. These include the control head, the microphone and its hang-up bracket, and the speaker. The control head along with the bracket for the microphone are mounted on the dash, so that it is conveniently accessible to the operator. The microphone may require connections within the control head or a plug connector may be provided, depending upon the equipment. Details are incorporated in the manual. The speaker is mounted in the most convenient place which will provide maximum audibility to the operator, and interconnections are made between the speaker and control head.

The fuse block and A power relay are next mounted, either on the engine side of the firewall or on the fender panel. The fuse block is located close to the battery, and the relay should be near the fuse block. The relay should be mounted with its contacts pointing down to avoid moisture accumulation inside the relay can. The cabling may now be installed.

Figure 1 shows the approximate path of the cables between the front units and the housing. The exact routing will depend upon the type of vehicle. (In some of the new cars, certain cable routings could conceivably require a longer cable than that supplied. For this reason, it is well to consider the cabling before mounting the individual parts--it may be necessary to relocate a few of the units. In most installations the cable is longer than necessary and the "extra" is coiled up, taped, and positioned out of the way.)

Always "Take Inventory" and Plan Each Installation.

We shall consider the antenna installation next. It may be located either in the center of the roof or on a fender. (See figure 1.) High-band or 450-mc equipment requires a roof mount for optimum operation. The length of a low-band whip antenna often makes it impractical to mount it on the roof top; unless maximum sensitivity is required, it may be mounted on the fender.

Where some peculiarity of a particular installation makes it impossible to follow the instructions in the manual, the solution must be logical. It must not interfere with the operation of the unit. When mounting the various units, all mounting screws must be firmly tightened. The correct size holes are specified to insure a good contact. If the vehicle is to be subjected to excessive vibration, suitable mounting nuts, bolts and washers may be substituted for those recommended in the manual. There is more to the complete installation than the mere mounting and cabling of the equipment. In addition to the noise filtering which may be required, the frequency, deviation and power must be checked in order to insure satisfactory system operation. The receiver, too, should be checked for sensitivity, squelch operation, and noise balance. The list which appears later in this lesson will serve as a guide for checking out the entire equipment. All readings which are taken should be recorded and retained for future reference.

Base Station Installation

Installation problems with base stations are different from those encountered with mobiles. The primary power available at the site must have sufficient voltage regulation. If not, some means must be provided for controlling the voltage at the equipment. Where the base station is remotely controlled, moreover, the control line must have certain critical characteristics. DC is normally used for operating the relays which switch the equipment between standby and transmit. Besides providing a good DC path, the control line must also carry the modulation, so its frequency characteristics must be satisfactory for voice transmission. The db loss of long lines is thus an important consideration.[1]

The site chosen for the base station equipment should be easily accessible to the serviceman and it must meet all code requirements (fire department, building department, electrical department, etc.)

The antenna must be carefully located so as to avoid interfering with other services. It must not cause intermodulation and desensitization in other local receivers due to its proximity with other antennas. At the same time, the site must provide complete coverage of the service area. The base station antenna must be mounted so that it will withstand the elements, and proper lightning protection is a must. Where a directional antenna is used, it must be properly oriented. The transmission line must be properly installed and secured and, where air or gas lines are used, the proper pressure must be established.[2] The line must be well grounded where it enters the building, and a drip loop should be used. This prevents water from entering the building or equipment via the line. In some base station installations, cavities are included to prevent interference; these must be properly tuned. Tower lights must be capable of being turned off and on at the proper time, and this must be verified.

Proper clearance for the front and back doors must be provided when installing the cabinet. Upright type cabinets must be securely bolted down and grounded. Emergency power, if provided, should be checked to make sure that it operates properly.

1. See "Hum Reduction in Remote Control Lines," reference M-8A.
2. See reference T-12A.

The Microphone of the Mobile Two-Way Radio Must be Within Easy Reach of the Operator.

The base station must be checked and a log established, according to FCC regulations. A record should be kept of all readings such as power output, receiver sensitivity, etc.

Noise Suppression in Mobile Equipment

Noise encountered in the mobile two-way radio equipment may be caused by the ignition and electrical system of the vehicle in which the equipment is installed, or it may be reaching the receiver through the antenna system along with the desired signal. Very little can be done about this latter so-called "ambient" noise, so it imposes a limit on the effective sensitivity of the receiver. It is not likely, for example, that the receiver will reproduce a 1-uv signal very well when the incoming noise is itself 2 or 3 uv!

While noise which is caused by the car's electrical or ignition system also places a limit on the weakest signal that can be successfully reproduced, something can be done about it--it can be suppressed.

Noise suppression requirements and procedures vary considerably for different vehicles and with different types of installations, the location and use of the system often determining what degree of noise suppression is required. Where the system has a lot of reserve, so that the signal at each of the receivers is high, it may not be necessary to provide much suppression; the signal may be sufficiently strong to override the noise. Where the vehicle operates in low signal areas, however, it is necessary to limit the noise to a level lower than that of the signal, if contact is to be assured. One factor limiting the amount of noise suppression which should be realized for this condition is the ambient noise; it would be useless to reduce vehicle noise to a level far below that of the ambient noise, for the latter will always limit the reception.

The procedure for suppressing vehicle noise follows two phases. First, there is the general procedure which should be followed in almost all vehicle installations. Second, there are additional steps that must be taken when such routine procedure does not accomplish the desired suppression.

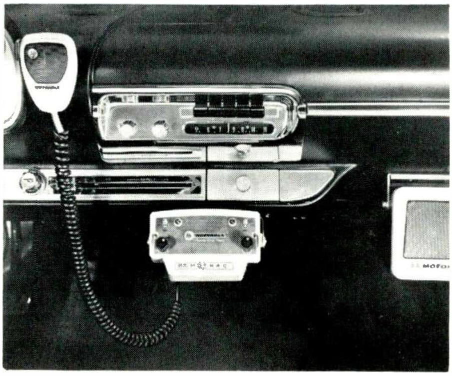
General Noise Suppression Procedure

If the vehicle is not already equipped with noise suppressors, the first thing to do is to install a suppressor in the center lead of the distributor cap and a capacitor at the armature lead of the generator. (Details for the installation of these units are given in the equipment instruction manual.) Most modern cars, have a by-pass capacitor at the generator, and the distributor suppressor alone remains to be installed. These units usually provide sufficient suppression of the ignition and generator noise without causing the radio to lose its ability to reproduce weak signals. Occasionally, the gauges produce some noise. This is suppressed by installing a capacitor at the gauge terminals, under the dash.

Receiver Noise Balance

Although the noise balance of a receiver is not a routine procedure in noise suppression, it is a regular part of the proper installation of the equipment. The noise balance of a receiver depends upon the last IF section being balanced with the response characteristic of the Permakay filter. Otherwise, the discriminator will fail to provide good noise idling and quieting. Before starting, we must assume that the receiver has been properly aligned; noise balancing should never be attempted without proper alignment.

For noise balance, with a signal applied from a signal generator and the motor running, so that noise is also present, the generator is adjusted to the center frequency and set at a level capable of producing about 20 db of quieting. The amount of noise is noted. The generator is then adjusted to either side of resonance and the amount of noise noted. If the zero discriminator output point coincides with the null point of the noise, the receiver is balanced. A perfect noise balance is not always realized, due to variations which may exist. Therefore, as long as the null is within 2 scale divisions of zero, the balance is satisfactory.



This Microphone is Within Easy Reach of the Driver.

With the generator once more at center frequency, the plate tank coil of the first 455-kc IF amplifier is adjusted slightly in either direction, the purpose being to decrease the noise at the speaker. In making this adjustment, it is important that the reading at metering position 2 does not decrease more than 0.5 microampere. If the reading is lower than this amount, the receiver sensitivity will suffer or, at least, the reserve gain will be sacrificed. In some receivers the plate tank of the IF stage will not show any appreciable change in noise balance, because of the loading resistors in the plate tank. With these receivers, it will be necessary to provide the noise balance by means of the tuned circuits in the first IF section.

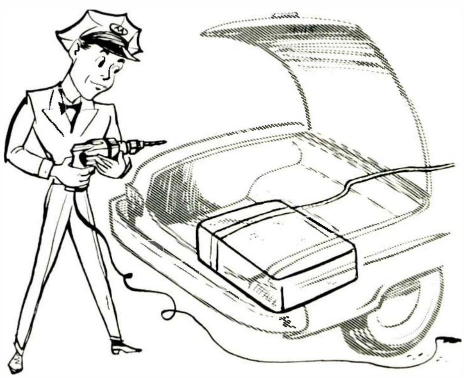
Locoting Noise Sources

After the general procedure for suppressing vehicular noise has been completed and the receiver adjusted for optimum noise balance, the noise input to the receiver may still be too high; further noise suppression may still be desirable. The first thing to do is to locate the source of the noise. Noise may be caused by the generator, the ignition system, the electrical gauges, or by static discharges.

The source of most noises can be determined from the sound heard in the speaker. Ignition noise is characterized by regular popping or snapping sounds, which follow changes in the speed of the engine. The ignition coil, distributor or spark plugs may be the actual source of ignition noise, the interference being radiated from the interconnecting wires.

A whining noise can usually be attributed to the car generator. This kind of noise should also follow changes in the speed of the motor.

Harsh, raspy noise, of a continuous character is usually caused by gauges: the most common offender is the pulsing type of temperature gauge. Popping noises, occurring only when the car is in motion, may be caused by static discharges from insulated parts of the vehicle. Erratic popping, which increases as lights and other electric accessories are turned on, are usually caused by miniature arcs resulting from the small voltages which exist between the vehicle body, frame and motor block.



Be Sure to Avoid the Gas Tank, Gas Line and Similar Parts of a Vehicle when Drilling Holes and Mounting Two-Way Radio Equipment.

Ignition Noise Suppression

The problem of suppressing ignition noise has been growing more acute with the widespread use of 12-volt electrical systems. This high-impulse type of noise is at once the most bothersome to radio reception and the most difficult to eliminate. Some of the more common causes of noise within the ignition system are: Distributor breaker points not operating properly, inefficient ignition condenser, corrosion and poor contacts within the system, and spark plugs improperly spaced or in poor condition.

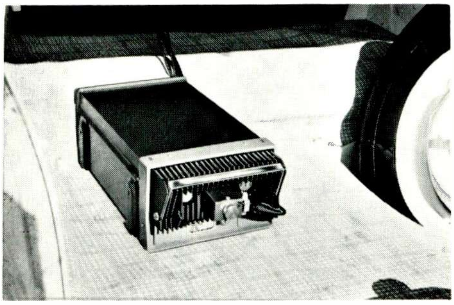
Figure 3 shows several noise suppression arrangements which can be applied to the ignition system. Circuit element 1 represents a 0.1 mfd capacitor inserted across the primary lead of the ignition coil to ground. Either a capacitor such as that supplied with the equipment or a special coaxial type capacitor may be used. (Coaxial capacitors are more effective in reducing severe interference.) This capacitor should be located right at the coil, and the lead to the grounding point should be as short as possible.

Circuit element 2 represents the suppressor mentioned above, placed in the distributor cap lead. This should be located as close as practical to the distributor cap. Circuit elements 1 and 2 are often all that is needed to provide the necessary suppression.

Ignition noise may be further reduced by using circuit elements 3 and 4. In any case, these two components should be tried first, for they are usually the most effective in reducing the noise. When resistance ignition cable (3) is used for greater noise reduction, care must be taken not to introduce too much resistance, thereby sacrificing the performance of the engine. (It is possible to cause rough idling, particularly in cool weather, by using too much resistance.) The resistive type spark plug (4) is often included in the newer cars. The only precaution to be observed here is to make sure that replacement plugs, when used, are of the correct type for the operation of the car and that the "gap" is correct. Many of the new cars have a resistance wire type harness between the coil and the plugs as standard equipment. When this is the case, it may be neither necessary nor helpful to use resistance plugs. Resistance plugs and ignition wires may usually be installed without causing trouble, however, in cars which have the higher ignition voltage.

Spork Plug Leods

Where stubborn ignition problems are encountered and the preceding remedies fail to provide sufficient noise reduction, it would be well to use an ohmmeter to check the continuity of each of the spark plug leads. There must be a path for DC. Where there is no DC path, the end connectors may be checked. If continuity is established by "squeezing" the terminal, the lead itself is probably satisfactory. Where the continuity still is intermittent, it is best to install a replacement lead, checking the new one first for continuity.



In Locating the Housing, Allow Plenty of Room for Servicing Trunk Mount Radios.

A minimum number of terminals should be used within the ignition system. Thus, it would be better to use a resistor-type spark plug or a resistance spark-plug wire than to use a regular spark plug or spark-plug wire and install separate series suppressors. If resistance wire is used, the amount of resistance added is established by the manufacturer of that particular car.

Ignition Noise

Ignition noise is coupled to the surrounding parts and reaches the two-way radio in several ways; one of the most common is direct radiation into the antenna. Resonant lengths of wire are common at high-band frequencies, and these act like a tuned antenna, radiating the available noise power quite efficiently. Ignition noise is also often coupled to low-voltage circuits. Spark plug leads should thus be separated from other wiring. The length of these wires should be changed in such instances. Shielded wire is another possible solution of difficult noise problems if the performance of the vehicle is not to be impaired.

Sometimes the distributor points undergo considerable arcing, and this causes interferences due to radiation from the associated primary wiring. Assuming that suppressors have been already installed in the primary lead and in the lead to the center connector, and that the leads to the spark plugs are all making good contact, the use of a coaxial type suppressor in the primary lead will prove the most effective. If the distributor itself is operating properly, the above steps should provide the necessary noise suppression.

Generator Noise Suppression

Generator noise is characterized by a high-pitched whine which varies with the speed of the generator. This makes its recognition a simple matter; if the noise changes with the speed of the generator, the generator is probably causing it, for there is nothing else in the car which produces this type of sound varying as it does with the motor speed.

Generator noise is usually the result of arcing between dirty or worn brushes and the commutator. In some cases, commutators may be cleaned with fine sandpaper but never with emery cloth. It is advisable to have this service performed by a competent specialist. Most of this noise can be held to a low level by keeping the generator in good operating condition.

Where generator filtering is required, a capacitor connected between the primary lead and a good ground makes an efficient suppressor. Coaxial capacitors are more efficient than ordinary capacitors over the entire noise range and they are universally preferred for maximum possible noise reduction.

Where the noise caused by the generator is unusually severe, a shielded wire, well-grounded at both ends, can be used between the generator and the voltage regulator. Heavy generator noise can also be suppressed by using an elaborate pi-type filter. These filters, which are connected directly at the generator, are usually available from the manufacturer.

Voltage Regulator Noise

Noise caused by the voltage regulator can usually be recognized by its raspy sound, the result of arcing at the regulator contacts. Where this noise is not excessive, filters may be added to the regulator. Otherwise, the best solution may be to install a new regulator! A coaxial capacitor will usually suffice at the lead to the generator, provided that the connection is close to the regulator and provided that the ground is good.

It is not permissible to connect such a capacitor at the generator field terminal of the regulator, for this will greatly reduce the useful life of the regulator. Instead, a small 1-watt resistor of about 3.3 ohms must be placed in series with the capacitor, as shown in figure 3. The capacitor will be considerably smaller than the others (usually about .002 mfd) and the resistor must be of the carbon type, not wirewound. It is usually unnecessary to use a capacitor at

Noise Produced by Ignition Systems Often Interferes with Mobile Two-Way Radio Communications.

the battery terminal of the regulator, although this may be advisable if it improves the noise level.

Gauge and Other Equipment Noise

Gauge noise is usually identified by a hissing or crackling sound in the speaker. In most instances the offending unit can be located by jarring the individual gauges while the ignition is on. Noisy gauges should be bypassed as near the noise source as possible, but it is also important to provide a good ground. Connecting wires which are close to the motor block provide a convenient ground point. The oil sender, with its low-pitched clicking sound, and the temperature gauge are among the commonest sources of gauge noise.

Noise is an inherent property of all moving parts which are ungrounded, or insulated from the rest of the vehicle. This includes the wheels, the front wheels in particular, for these are often insulated from the ground by wheel grease. The accumulated static charge produces arcs, which cause noise in the radio equipment. Standard ground brushes and springs will usually reduce the noise from this source.

While most parts of the vehicle are bonded in order to provide a good ground return, occasionally some part of the car body exhibits poor conductivity and becomes a source of noise radiation.

The muffler and tail pipe assembly, for example, is often insulated from the car frame and it may be necessary to ground the tail pipe at several points between the motor and the rear of the vehicle. The hood, too, is often insulated from the car frame, requiring bonding by heavy copper braid and contact wipers.

Although the motor is already grounded to the car frame, it sometime becomes necessary to provide additional ground straps at each corner of the motor. This is particularly true where the ignition noise is too high to be corrected entirely by the methods described above.[3]

Preventive Maintenance

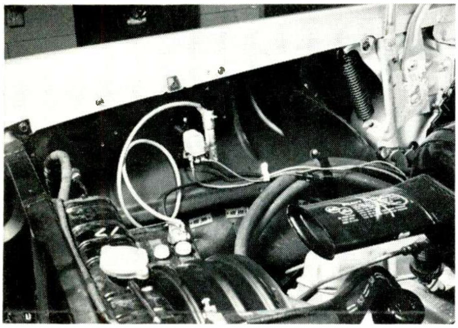
Preventive maintenance, the practice of anticipating trouble and avoiding it before it starts, is a practical method of minimizing repair expense and "outage" time.

A comprehensive preventive maintenance program, when properly undertaken, will more than pay for itself and benefit both the user of the equipment and the service technician performing the maintenance.

The following case history illustrates the value of preventive maintenance.

A new two-way system has been properly installed and checked for

3. See "Suppression of Ignition Noise in Mobile Equipment," reference M-8B.



Here We See the "A" Relay and Fuse Block Mounted on the Fender Panel, near the Battery

normal operation and it is now up to the serviceman to maintain the equipment. Because the equipment is new and everything is working satisfactorily, the system will probably give months of satisfactory and normal service.

Eventually, however, complaints begin. Weak signals formerly received are no longer being heard, reception has become distorted, etc. The serviceman, on checking the system, cannot find any particular fault which is causing the trouble, so he adjusts the transmitter deviation and frequency until the system seems to have been restored to its normal condition--at least, the messages get through! The same trouble starts again. However, this time the complaints start sooner and they are more frequent.

The answer, of course, is that the serviceman has failed to check the entire system, and to maintain each transmitter, receiver and power supply at or near its normal performance. The power output of the transmitters gradually decreases due to tube aging; the sensitivity of the receivers also suffers, for the same reason, and the output from the power supplies decreases due to worn-out vibrators.

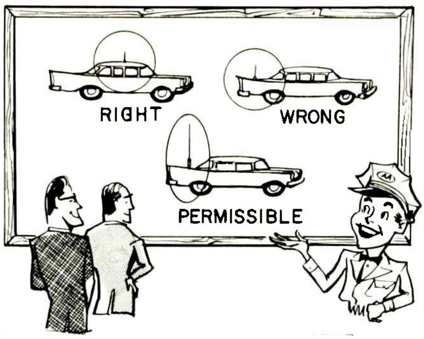
The failure of the serviceman to keep the equipment in normal operating condition forces him to perform a lot of extra work and he is constantly answering emergency service calls. It is also likely to produce an undesirable reaction on the owner of the equipment. He loses confidence both in the serviceman and in the manufacturer. Moreover, if he knows of other systems of the same make and type that give good service, he may readily see for himself that the serviceman is derelict in his duty, that he is actually falling down on the job. This owner of the equipment in the above example is actually losing money. He loses the advantage of having his two-way system in operation when it is needed; moreover, his cars and trucks are being tied up unnecessarily for service.[4]

Sources of Trouble

A good way to start is by analyzing the various sources of trouble. But first we must be able to recognize all the possible sources of trouble that can exist within the system. These, together with their accessories, include (1) the

4. See "System Maintenance of Two-Way Radio," reference M-8C.

primary power circuit, (2) the receiver, transmitter, power supply and control head including the microphone and speaker, (3) the intercabling between the units and (4) the antenna system.



Wherever Possible the Mobile Antenna Should be on the Roof Top. Long (Lo Band) Antennas may be Mounted on a Fender if Necessary.

Primary Circuit

Under this head we must consider the various types of primary power commonly encountered in operating the equipment. The battery and generator system in the mobile vehicle is often a source of trouble. Where the battery of the vehicle furnishes the power to operate the equipment, we must remember that poor power output from the transmitter and poor receiver sensitivity may be due to trouble in the primary power source. The best test of a battery is probably the terminal voltage for a specific current drain (load). Commercial testers for checking batteries are available, but a battery usually gives plenty of warning when it is on its last legs. Batteries seldom fail all at once; they usually undergo several periods of abuse before they fail completely.

An old worn-down, or undercharged battery will measure no more than 6 (or 12) volts at the terminals and even less at the radio equipment. Depending upon the current taken by the equipment and the resistance of the cabling components, the voltage at the radio will be 0.5 to 0.7 volt lower than at the battery terminals. If the voltage drop between the battery and the radio is excessive, the reason may be found in a poor connection at the fuse block, relay, or ground connection, or the cable itself may be defective.

Relay contacts often become defective and require service or replacement. Fuses may not make proper contact in their holders, or they may develop high internal resistance. (A maximum drop of 0.1 volt is all that should be encountered across the fuse assembly.) Connections may loosen as a result of vibration and must be tightened or resoldered, whichever applies. Fuse contacts may become corroded, or loosen because of vibration.

In 12-volt systems certain conditions may cause the operating voltage at the radio during standby operation to be well above a safe value, resulting in premature failures within the equipment. Where these high voltages are noted it may be well to install a

Motorola primary voltage regulator such as that discussed in the lesson dealing with power supplies.

Receiver, Transmitter, Power Supply and Control Head

Most of the trouble shooting performed in 2-way equipment seems to be within the receiver and transmitter--possibly because the majority of troubles are found in these units (the receiver and transmitter in particular).

In the receiver, the sensitivity may become poor, its frequency may change, the squelch may be inoperative; a great many other troubles are possible. The most common faults in the transmitter are lack of power, off-frequency operation, and either too much or too little deviation. The most common trouble encountered in the power supply is a decrease in output voltage. While this usually resolves itself into a defective vibrator or inefficient rectifier. Other possibilities, such as a low primary source, for example, must never be overlooked.

Intercabling

Intercabling faults are most common where the equipment is subjected to considerable vibration. (Plugs sometimes become loose or connectors may develop a poor contact.) Cables may also rub against some sharp corner and produce a break or a short. A careful check of all cables and connectors is a must.[5]

The Antenna

Antenna systems are an often overlooked source of trouble. Broken antenna rods, shorted transmission lines, misoriented directional antennas, water-logged connectors, all constitute an enemy to normal operation of both the receiver and the transmitter.

How Often?

The question as to how often a system should undergo a routine check depends upon the type of equipment, its use, and the type of vehicle. Where the equipment is in continuous use and where it is installed in heavy trucks which are subject to a lot of vibration, it is likely to require close attention; a monthly checkup is certainly warranted. On the other hand, some installations may be put to only a limited use in a given period, in which case monthly inspections may not be required. In general, it would be reasonable to say that all units should be inspected after each 500-700 hours of operation. Of course, the FCC requires all transmitters to be checked at least once every six months for proper frequency, deviation and power.

5. See "On Locating Intermittants," reference M-8D.

How Are Monthly Checks Made?

For convenience we will refer to all preventive maintenance checks as monthly checks, for in most instances this will be the prevailing period. The question is to determine what this check consists of--how is it performed? In general, the procedure is threefold: listening, visual inspection, and meter measurements.

By listening to the receiver output the trained technician can often spot a defect. The sound may be weak or distorted, or the noise may be weak when the receiver squelch is open. With experience, the normal signal level at certain locations becomes known, and immediate comparisons can be made. Noisy reception, "hash" in the background, and similar effects also indicate improper operation.

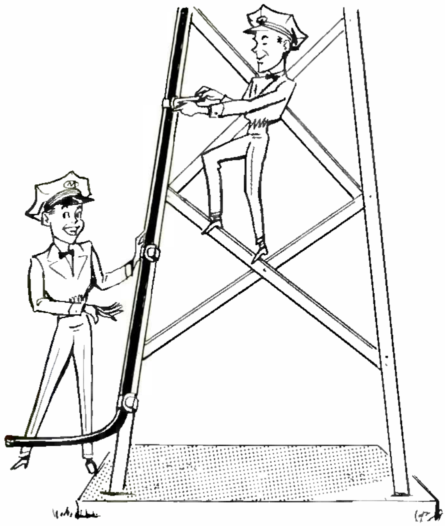
Loose bolts, screws, and clamps, worn cables and mike cords, burned out pilot lamps, and relay arcing, are among the many things which can be located by means of visual inspection. Trouble can also be anticipated by visual inspection. It is quite possible, for example, that a loose plug or connector may not be a source of present trouble, and the equipment may not operate any better after a connector has been tightened; however, the loose connector could eventually be a source of intermittent trouble and might even result in damage to the equipment.

The visual inspection must also include searching for dirt--dirty contacts at relays, dirty or worn dynamotor brushes, corroded fuse holders, and the like. Cracked insulators and tubes operating "red-hot" are also located by means of visual inspection.

Visual inspection also includes what might be called "touch" inspection. Used with caution, the fingers make good detectors of improper temperature, both high and low. Fuses and fuse holders having poor contacts are readily located by the sense of touch. Transformers, relay coils and other units can also be checked by the fingers for overheating. A crystal holder and heater assembly which is cold, or a tube that normally should be warm but isn't, can be detected by "feel."

Caution must be exercised, however, for certain units (tubes and high-wattage resistors in particular) may be too hot to touch without burning one's fingers. Care must be taken that the high voltage circuits are not touched. For this reason the power should first be turned off. (Most components will retain their heat for some time afterward.)

Meter readings are perhaps the greatest aid for evaluating the operation of the receiver and the transmitter. They can be quickly taken, and they give an immediate idea of receiver sensitivity and transmitter power output. Moreover, with the base station signal



In Base Station Installations the Transmission Line Must be Well Secured to the Tower.

coming into the receiver (assuming the transmitter frequency is correct), the netting of the receiver frequency to that of the base transmitter can be effected immediately by this means. Netting means that all the units within one system are placed on the same frequency.

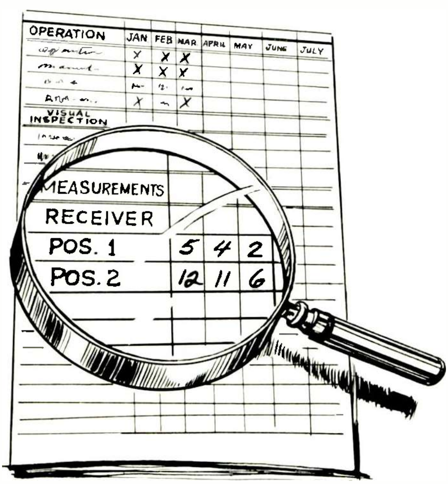
A frequency monitor, a deviation indicator, and a wattmeter can be used to measure the frequency, deviation, and power output of the transmitter; voltmeter readings at the battery and at the input to the equipment indicate the condition of the primary power source. Because the transmitter and receiver both depend upon the supply voltages for normal operation, these voltages must be included in the routine check. The power supply voltages can be conveniently determined by the use of meters.

Specific Checks to Make-- Check List

Figure 4 shows a check list which can be used when making monthly inspections. (The procedures listed are those which have been previously discussed.) This list applies to mobile units only. For base station installations, certain changes would have to be made in the list. The specific items thus vary from system to system, depending upon the service, the nature of the equipment or other factors, but this is not important. What is important is that certain physical and electrical aspects of the equipment are inspected systematically.

While the length of this list seems to be rather formidable at first glance, the complete check can be completed in 30 minutes by a competent technician. This is assuming, of course, that no great amount of service work or trouble shooting is involved. The list need not be followed in a definite sequence. It may be desirable to take the meter measurements and net the frequency of both the receiver and the transmitter before performing the operational check. Or, if the operational check is performed first and any adjustments are made on the equipment, a final operational check should then be made.

No check list is intended to be an absolute must for each inspection. In systems where the audio quality is good, for example, it may not be necessary to check the amount of deviation every month nor will a frequency adjustment be required if the receiver frequency is closely netted to that of the base transmitter. (This check is made by merely observing the meter reading at position 4 with the base carrier applied.)



A Record of Routine Meter Readings Allows the Serviceman to Correct Minor Troubles, thereby Avoiding "Outages" and Expensive Repair Costs.

Off-frequency operation of some of the equipment is often a prime cause of poor system performance. Hence, for the purpose of maximum system operation, it is important to keep the system netted. Without system netting, full advantage of the system cannot be realized or maintained. System netting is even more essential to narrow-band (split-channel) operation.

Routine observation of transmitter deviation also pays off in continued good performance, for full advantage of FM communication cannot be realized where the system is either underdeviated or overdeviated. A word of warning in this matter is apropos at this point. It is almost never necessary to change the setting of the deviation control at the transmitter. If the deviation is not correct, the serviceman should find out why it has changed and correct the trouble at the source, rather than compensating for this trouble by operating the deviation control. To do so may correct the transmission for the time being but it will not correct the original fault, and future trouble may be expected.

The advantage to the serviceman in making and recording these checks will be evident from the following example. Let us suppose that the reading at the grid of the final stage in the transmitter (position 6 on the meter) shows a gradual decrease over a period of several months. The individual decrease for any one month may not be great enough to require attention, but after several months it becomes too low to be disregarded. By having a record of this gradual decrease, the serviceman immediately knows that this should be checked carefully, for if the drive to the final becomes too low, the tube may be damaged. By maintaining the grid drive at the required level, the life of the final amplifier tube is increased and in this manner its premature replacement is avoided.

Besides saving his own time, the serviceman who keeps a record such as shown in figure 4 will be in possession of a valuable tool for maintaining satisfactory relations with his customers. For one thing, the serviceman will find it convenient at some time or another to haul out these records and show the customer just how well his equipment is being watched. Where the customer is paying a fixed amount every month for each unit being serviced, he may have been wondering just what he was getting for his money. Without such a check list it may be difficult to convince certain individuals that they are spending their money wisely. The fact that you, the serviceman, maintain such a record and that you can tell the customer exactly what you have done to each of his units each month immediately classifies you as a businessman who takes care of his job in the proper manner.

Moreover, when you send your monthly bill to your customer, it is well to enclose a summary showing the various parts that have been used and the troubles that were found (and corrected) in each unit.

But we haven't mentioned the greatest advantage of all. By promptly correcting the trouble in a unit when it is not up to par, many breakdowns in the equipment are avoided; the customer gets the maximum use of his radio equipment and the amount of time lost in tying up the vehicles while the radio is being fixed is minimized. This is probably the greatest factor of all to use in selling your services to the customer.

Schedule Monthly Checks

All monthly checks should be performed on a scheduled basis--a particular day of the month should be reserved for checking the equipment for a particular customer. This again is good practice in the eyes of the customer. He is more likely to be satisfied with this arrangement, for he can schedule his vehicles accordingly. In the absence of such a schedule, you may find yourself wasting valuable time waiting for several hours to check a vehicle that is in use. Besides wasting time in waiting to service the vehicle, you leave a bad impression on the customer. Again, if you happen to catch a certain vehicle for a few minutes and start your inspection, it may be called into service right in the middle of the job. The only alternative is to wait until the car returns--more time wasted.

Much time is saved by having a definite checking schedule for each vehicle; and the entire operation becomes more efficient. Certainly more units will be checked in a given time, compared to the number that can be checked when you have to wait until the vehicles are available. Moreover, if various test instruments have been set up for these checks, it is obviously more efficient to check the complete vehicle at one time. Where only half of it can be checked, the serviceman must get these instruments ready again at another time, in order to test the rest of the units.

Base Station Checks

The tests prescribed in figure 4 apply particularly to mobile equipment; several additional checks must be performed at base stations, especially if the base station is remotely controlled. At a base station, we seldom have the problem of low primary power to contend with but there is always the problem of voltage regulation. Poor regulation of the AC source can seriously affect the operation of the equipment. It is also important to make periodic checks of standby equipment (when such equipment is provided) in order to make sure that it will operate as required in case of power failure.

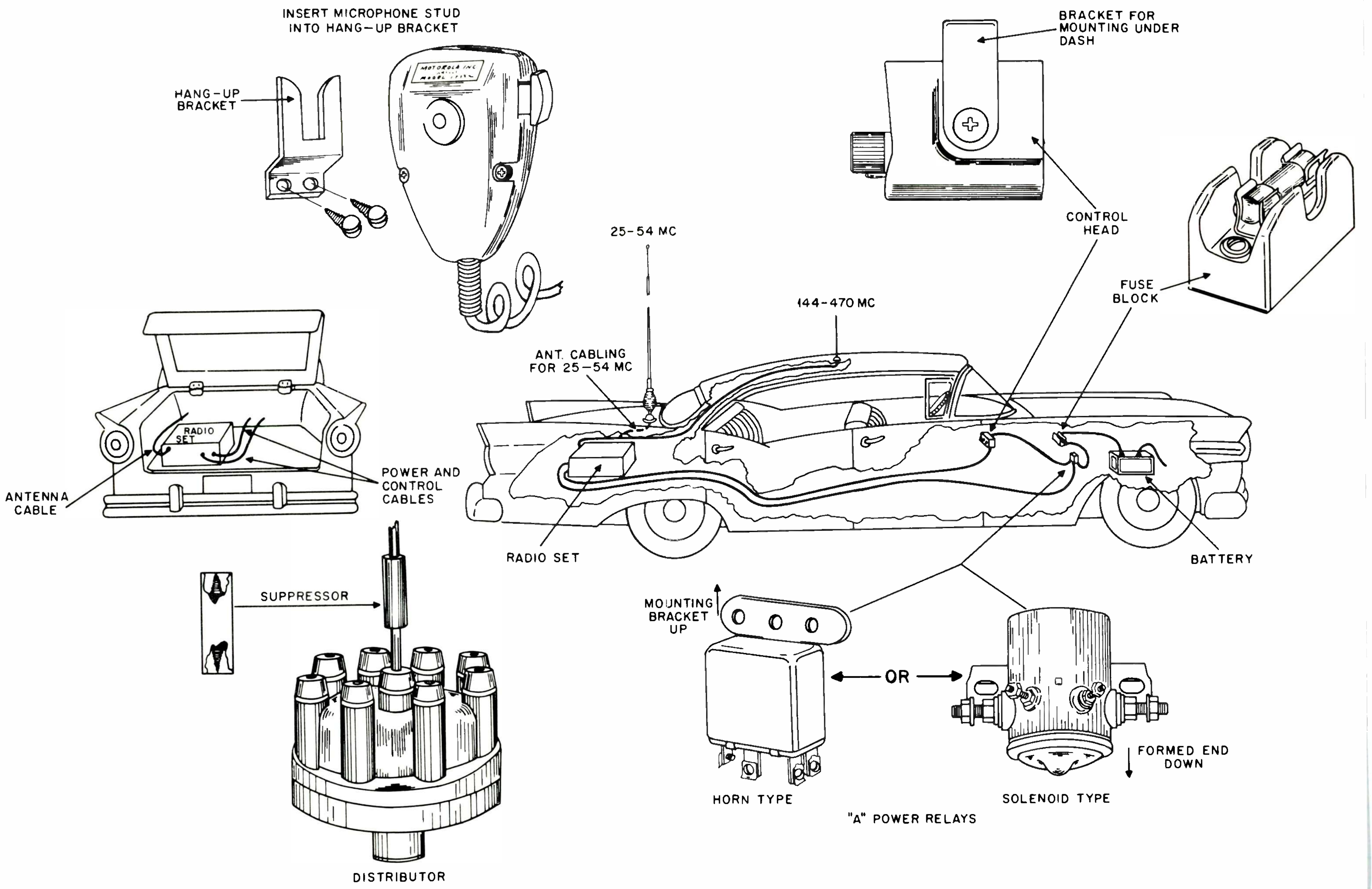
Where base station antennas are mounted on towers, lights may be required and they must be checked. (The FCC has issued rigid regulations on this subject which must be followed.) Where remote control is used, proper line voltages are a must. This is true whether the controlling voltages are required to switch frequencies or to establish the level of the modulating signal. Line levels, hum balance, and other adjustments should be checked periodically.

The specific tests to be made on a given base station installation will depend on the equipment being used. The specific factors to be checked each month may be determined from the instruction manual and a chart prepared accordingly. This chart not only becomes a handy device but, with proper notations added, it will satisfy the FCC regulation requiring that a log be kept on all service and adjustments of the base transmitter. The chart must be kept at the base station and be available for inspection at all times.

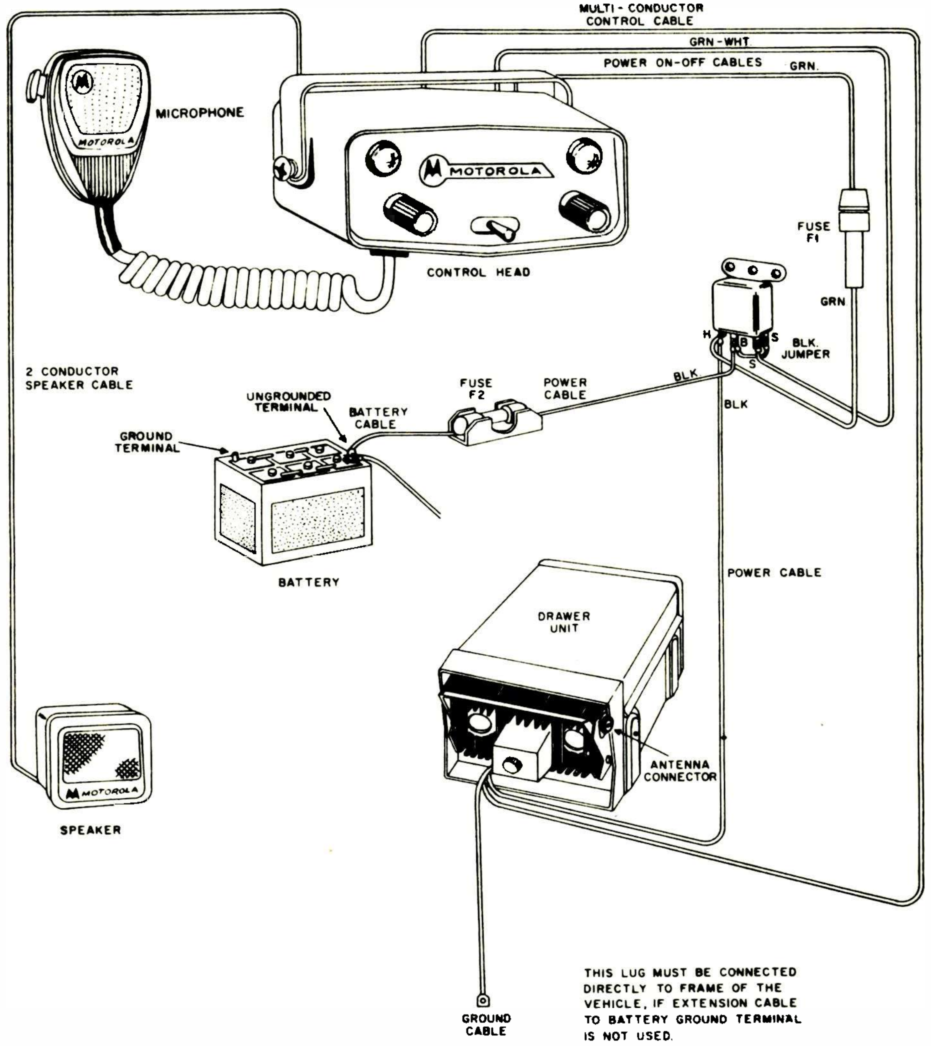
Specialized Equipment

Certain specialized equipment (such as the Motorola Private Line, Quik-Call, etc.) requires additional tests. Again, the specific checks will depend on the equipment and the application to which it is put. The variations are too numerous to list here, but details will be found in the appropriate service manuals.

STUDENT NOTES

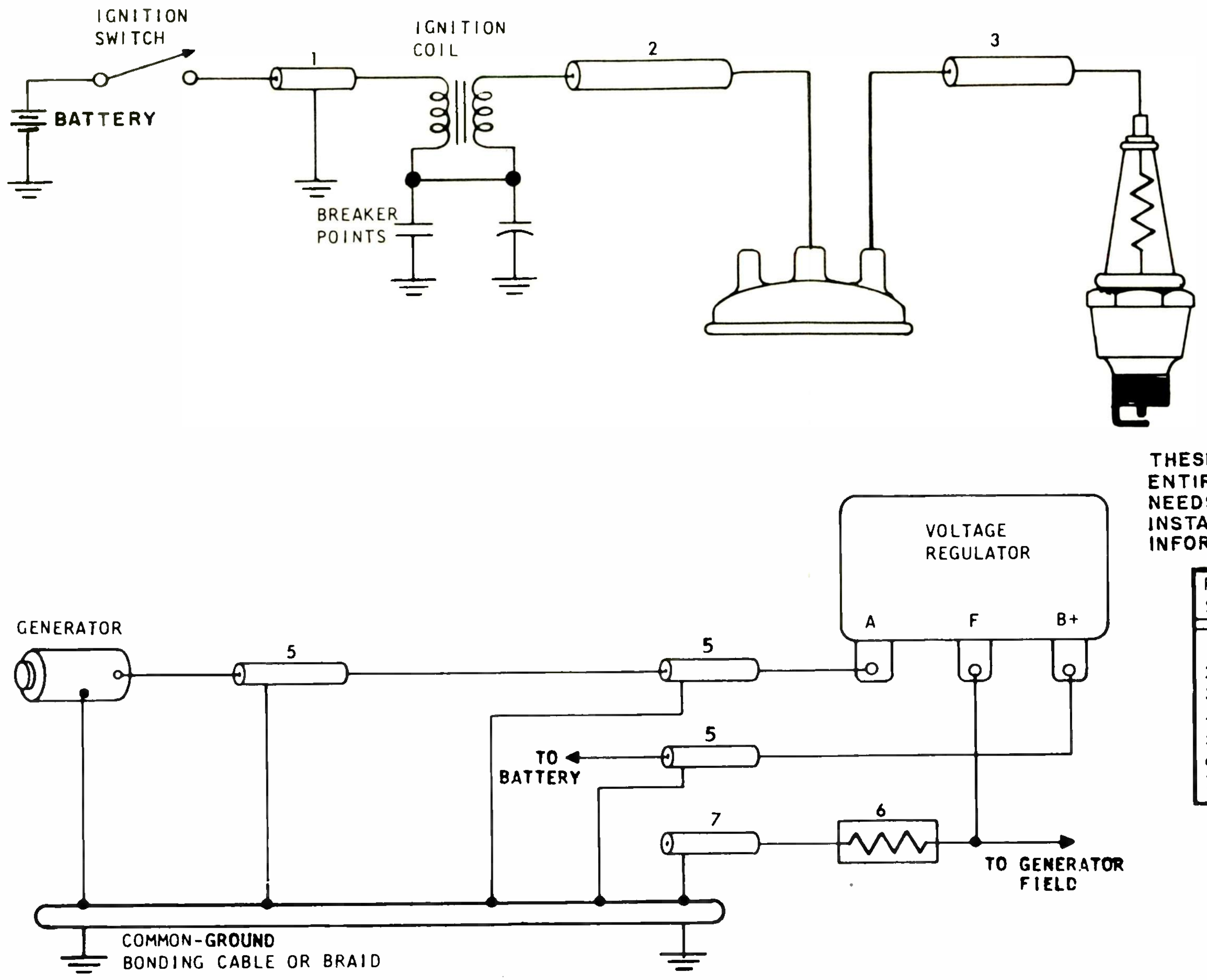


MOBILE REAR MOUNT INSTALLATION DETAIL
FIGURE 1



REAR MOUNT MOBILE CABLING DETAIL
FIGURE 2

STUDENT NOTES



THESE REMEDIES MAY BE USED IN ITS ENTIRETY OR IN PART, ACCORDING TO THE NEEDS OR LIMITATIONS OF THE INDIVIDUAL INSTALLATION. (SEE TEXT FOR COMPLETE INFORMATION.)

REF. SYM.	DESCRIPTION
1.	COAXIAL CAPACITOR, 0.1 MF.
2.	SUPPRESSOR CABLE
3.	RESISTIVE WIRE
4.	RESISTOR SPARK PLUG
5.	COAXIAL CAPACITOR, 0.5 MF.
6.	CARBON RESISTOR, 3.3 OHMS, 1W
7.	BY-PASS CAPACITOR, .002 MF.

TYPICAL NOISE SUPPRESSION DETAIL
FIGURE 3

MONTHLY INSPECTION CHART

MOBILE 2-WAY RADIO

SYSTEM ____________ UNIT# ____________

1) OPERATION	JANUARY	FEBRUARY	4) MEASUREMENTS	JANUARY	FEBRUARY
Receiver Squelch	X		Receiver		
Receiver Volume	X		Test Set Position 1	5	
Audio Output	Normal		2	12	
Reception	Normal		-4	+1	
Mike Button	X		5	28	
Contact to Base	Report Normal		6	24	
Contact to Others	Weak to Mobile #2		(Vol & Sq Clockwise) 8	15	
Contact on Freq #2	X		20-db Quieting	.5 uv	
2) VISUAL INSP.			B Supply	190 V	
Green Light	X		Receiver Netted to Base	X	
Red Light	X		Noise Idling	-1	
Mike Connector	X		Transmitter		
"A" Power Relay Connections	X		Test Set Position 2	22	
Fuse Contacts	X		3	13	
Battery Connection	X		-4	8	
Power Plug at Unit	X		5	16	
Ground Terminal	X		6	11	
Control Head	X		(B+ times 20) 7	340 V.	
Unit Mounting	X		(A supply X 0.3) 8	6 V.	
Antenna Mounting			Motor Idling		
Antenna Connector			PA	25	
3) TOUCH CHEEKS			Frequency Netted	X	
Rec. Crystal Warm	X		Deviation Check	X	
Trans. Crystal Warm	X		Mike Output	X	
Transformers Normal	X		Power Output	25 Watts	

Check Conducted By: E.M.
Date: JAN. 4/58

FIGURE 4

national

MOTOROLA

RADIO COMMUNICATIONS

service

A TWO-WAY RADIO COMMUNICATIONS TRAINING PROGRAM

LESSON MA-7
MAINTENANCE

Test Equipment

MOTOROLA TRAINING INSTITUTE

A TWO-WAY RADIO COMMUNICATIONS TRAINING PROGRAM

LESSON MA-7
MAINTENANCE

Test Equipment

—one of a series of lessons on two-way FM communications—

MOTOROLA TRAINING INSTITUTE
4501 W. AUGUSTA BLVD., CHICAGO 51, ILLINOIS
APPROVED BY THE STATE OF ILLINOIS
DEPT. OF REGISTRATION AND EDUCATION

PREFACE

This is one lesson of a complete Motorola Home-Study Course which presents to the Service Technician both the principles of operation and the maintenance of two-way FM radio systems. The program covers mobile, portable and base station equipment, including the latest transistorized units.

TEST EQUIPMENT

LESSON MA-7

TABLE OF CONTENTS

NOTICE

Diagrams and figures referenced in text are "fold-outs" in back of each lesson, for use while studying. The Examinations are also there.

Building contractors, ranging from plumbers to roofers, find that two-way radio enables continuous management supervision. Workmen's efficiency is also increased by the ability to closely control schedules, vehicles and supplies.

TEST EQUIPMENT

Lesson MA-7

Introduction

In this assignment we shall discuss those pieces of test equipment which are used in servicing two-way FM communications equipment. Our study will include the operation of frequency meters, deviations meters, signal generators and wattmeters, and some thought will be given to the application of the oscilloscope and AC voltmeter.

It will be recalled that the FCC requires frequency and deviation measurements of each transmitter to be taken at least once every six months. The serviceman must therefore be able to use these instruments intelligently. We shall begin our discussion with the frequency meter.

Frequency Meters; Motorola Monitor

It is only fitting that we should start with the Motorola FM Station Monitor. This instrument serves both as a deviation meter and as a frequency meter, but for the moment we will be concerned only with the frequency measuring function.

The Motorola FM Station Monitor is available in two models (for high and low bands, respectively) but the principle of operation is the same for either. Thus, while we shall be discussing the use of this instrument for high-band measurements, its use for low-band measurements will follow the same principles.

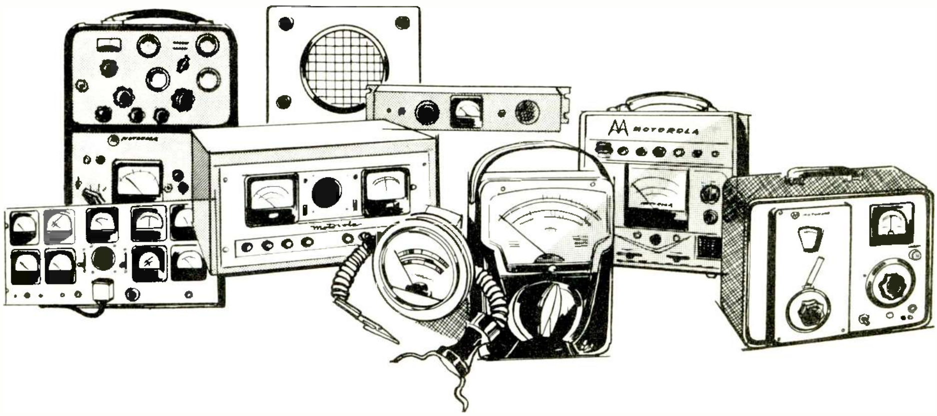
The first step is to check the 5-mc calibrating crystal oscillator of the instrument against the highly stable signal of station WWV, operated by the Bureau of Standards. A WWV receiver is included for this purpose. Depending upon the location, the WWV signals of 5 and 10 mc or of 10 and 15 mc are used.

Figure 1A shows a block diagram of the arrangement. The WWV receiver is first tuned for station WWV. The 5-mc oscillator is then adjusted to zero beat with WWV. By exercising care in this adjustment, the oscillator can be held to within one or two cycles of 5 mc.

The second step is shown in figure 1B. The WWV receiver is turned off and the 5-mc oscillator switched to the input of the control receiver--which is to be tuned to 150, 155 or 160 mc.

Let's assume that the receiver frequency is 150 mc. The receiver is calibrated at exactly 150 mc by tuning it for zero discriminator output on the 30th harmonic of the 5-mc oscillator. Even with an oscillator variation of a few cycles (multiplied 30 times), the 150-mc receiver will still be within 100 cycles of exact frequency. For all practical purposes, this error is insignificant.

(as determined in step 3) is substituted (by means of a switch) for the 5-mc crystal in the oscillator. The signal is then mixed with the carrier frequency being measured, and the output applied to the control receiver. The carrier (as-



The Proper Test Equipment is Essential to Quick and Intelligent Service of Two-Way Radio Equipment.

Before making any frequency measurements, we must determine the frequency of the crystal which is to be used. This will depend on (1) the frequency of the transmitter to be measured, and (2) the frequency of the control receiver. Let us assume that we wish to measure the frequency of a transmitter operating at 152.5 mc and that our control receiver frequency is 150 mc. The difference frequency between the transmitter (152.5 mc) and the control receiver (150 mc) is 2.5 mc. This is the required crystal oscillator frequency (step 3, figure 1C). Step 4 figure 1D shows the actual measurement of the RF frequency. A crystal of the required frequency

sumed to be exactly 152.5 mc) beats against 2.5 mc and the difference is 150 mc, the frequency of the standard receiver. The discriminator output will be zero, indicating that the carrier is at its exact channel frequency.

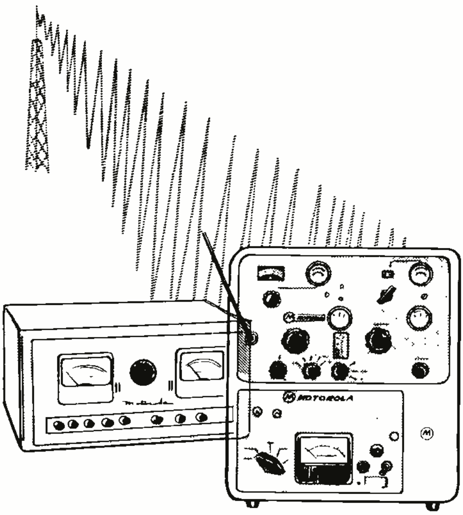
If the RF is not on exact channel frequency, however, the signal input to the control receiver will be off by the same amount, and this will be recorded by the meter. For example, suppose the RF frequency is actually 152.502 mc. When this beats against the 2.5-mc oscillator the difference frequency is 150.002 mc and this signal, when applied to the 150-mc receiver, will produce a difference of 2 kc at the discriminator. The calibrated meter will record a + 2-kc variation.

If the 2.5-mc crystal oscillator is off frequency, there will be an error in the frequency recorded even though the RF is at the exact channel frequency. Thus the accuracy of the measurement depends upon the accuracy of the crystal. Let's see just how much the crystal affects this accuracy. Suppose the crystal has a guaranteed accuracy of .002 per cent. This means that the 2.5-mc oscillator will be within 50 cycles of 2.5 mc (2,500,000 times .00002). Beating this oscillator directly against the RF signal means that the difference frequency must be within 50 cycles of its proper frequency. Now 50 cycles, as far as 152.5 mc is concerned, represents a variation of only .000033 per cent. Thus the monitor for this particular measurement is extremely accurate. The "improvement" in accuracy from that of the crystal to that of the RF being measured is determined by the ratio of the RF frequency to that of the crystal. Thus 152.5 mc to 2.5 mc represents an improvement of 61 to 1. Where the selected crystal frequency is higher than 2.5 mc, the improvement factor will be correspondingly less. The improvement will be less for low-band monitors than for high-band monitors, because of the lower RF frequency.

Besides frequency measurements, the FCC also requires a routine check of the transmitter deviation. The Motorola Monitor can be used for this purpose, the deviation-measuring system being as follows:

The deviation meter of the monitor is located at the output of the audio section of the standard receiver; hence the output voltage will vary with the gain of the audio stages. Internal calibration is provided, however, in order to insure that the recorded deviation is correct. The output of an internal audio oscillator is set to a predetermined level (as measured by the meter), and the gain of the audio section is then adjusted by applying this known audio voltage to the audio amplifier and setting the volume control for a specified output voltage. In this manner the gain of the entire audio section is maintained at the correct level, and the deviation shown on the meter will be correct. The procedure (fig. 2) is as follows:

First adjust the oscillator output for the correct voltage. This is done by connecting the deviation meter to the output of the oscillator, and adjusting the oscillator output to a specified level. This level will vary with each instrument, but a tag will be found on the unit which provides the correct reading. The next step is indicated in figure 2B. The audio oscillator is applied to the receiver audio section, and the meter is placed at the output. The volume is then adjusted for a 15-kc deviation reading on the meter. With the input and output voltages known, the correct audio gain of the receiver is established. Thus the meter will indicate accurately the deviation of the incoming RF signal, for the audio output of the discriminator is determined by the deviation of the signal into the discriminator and this discriminator output is applied to the audio section of the receiver.



Either the Motorola Monitor or the Frequency Meter may be Used to Determine the Frequency of a Transmitter.

The RF is now applied to the monitor. This procedure is much the same as for frequency measurements, but the controls have now been adjusted to show the amount of deviation. The manner of adjusting the transmitter control will differ according to the type of test modulation, whether sinewave or voice. The instruction manual for the instrument should be consulted. It should be kept in mind that the monitor meter movement responds to average readings of the applied signal, although the meter dial is marked in peak deviation. When the modulation signal is sinusoidal, the peak and average readings have a normal relationship and the meter reading is accurate. In the case of nonsinusoidal modulations, however, the actual peak deviation may not coincide with that shown on the meter.

Pursuing this subject further, only when the audio voltage is a sinewave will the relationship between the average value and the peak value result in a correct meter indication. The average and peak values of other waveforms may have different relationships and the peak indication shown on the meter will not necessarily be the true peak deviation. This must be taken into consideration when using the Motorola Monitor for measuring deviation (and adjusting the transmitter modulation).[1]

Depending upon the equipment available and the type of modulation, there are several different procedures for measuring deviation. We shall discuss them briefly.

Assuming that we are to use the Motorola monitor to measure deviation (of a Motorola G-type transmitter) resulting from voice modulation, we introduce a sustained "Ah-h-h-h-h" of good volume at

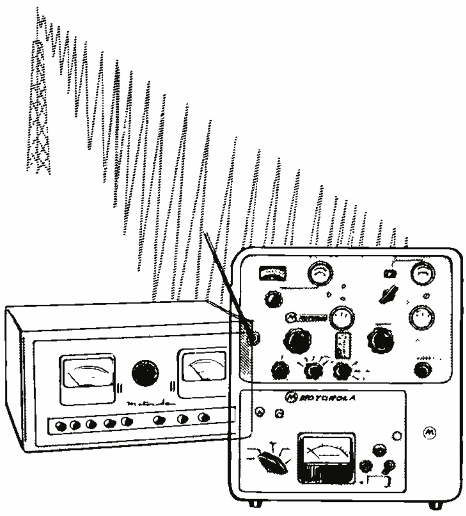
1. See reference M-6, "Let's Measure Modulation."

the transmitter microphone. The reading on the monitor meter should be about 12 kc. When we talk into the microphone, the average deviation will read about 7 kc on the meter, with the peaks at about 10 kc. The true deviations are actually higher than these indications, but the meter does not follow the instantaneous modulation of the voice signal.

Deviation may also be measured by means of a 1000-cps audio oscillator, an AC voltmeter and the monitor. With an audio input of at least 1 volt to the transmitter, the monitor should read 13 kc. This reading is lower than the true deviation of 15 kc, due to the variance of the average-peak relationship of the modulating waveform when the audio circuits of the transmitter are in full clip.

Another, and very reliable, means of determining the deviation requires the use of a scope, which must first be calibrated so that the amount of vertical deflection in relation to the deviation is known. For this purpose, the scope is connected to the output of the discriminator in the monitor, and a 1000-cps audio sinewave signal is applied to the transmitter input. This signal must be kept below the clip level during the calibration procedure. The audio is adjusted for a 10-kc reading on the monitor meter and the scope vertical gain is adjusted for a convenient deflection such as 10 full squares on the screen. Each square now represents 1 kc of deviation and we have a very sensitive indicator. Any means may now be used to modulate the transmitter and the scope will show the true deviation.

The above discussion is based on a system deviation of 15 kc. Where the deviation is limited to 5 kc, we use this as the maximum value, with 3.5 kc now corresponding to the 13 kc mentioned above. For 5-kc deviation systems, the scope again is an accurate and convenient means of measuring deviation.



The Motorola Monitor and Frequency Meter will Also Measure the Deviations of an FM Transmission.

Heterodyne Frequency Meters

There are several types of frequency measuring meters, most of which make use of a highly stable and carefully calibrated oscillator. This oscillator is heterodyned or beat with the carrier to be measured. When a zero beat occurs, the calibrated oscillator is at the same frequency as the unknown carrier; the frequency may then be either read directly on the dials of the calibrated oscillator or determined from previously prepared charts. The basic system is shown in the block diagram of figure 3A.

The carrier which is to be measured is applied to a mixer along with the output of the calibrated oscillator, and the oscillator is adjusted to the approximate frequency of the carrier. As the frequency of the oscillator swings through the frequency of the carrier, their difference frequency will be heard in the headphones; the operator will first hear a high-frequency sound which gradually decreases in frequency until the zero beat is detected. As the oscillator frequency is further varied we again hear a difference frequency in the phones, only this time it starts at a very low frequency and the frequency increases until it is beyond the range of the equipment or the hearing range of the operator.

At zero beat, the oscillator frequency is the same as that of the carrier, so the carrier frequency is established by determining the frequency of the oscillator. On some instruments the frequency is read directly from the instrument dials; on others, it is necessary to determine the frequency from charts supplied with the instrument.

Without some means of calibrating the variable oscillator of the heterodyne type of frequency measuring instrument, the guaranteed accuracy would be poor and the instrument would not be acceptable for measuring the frequency of two-way communications transmitters. (The FCC requires that the accuracy of the instrument be twice as good as the required stability of the transmitter.)

In order to provide this higher degree of accuracy, a calibrating, crystal-controlled oscillator is included in the equipment of figure 3A. The frequency of the variable oscillator may now be calibrated against the crystal oscillator at the fundamental crystal frequency, at any harmonic of the crystal frequency, or at any combination of harmonics of the oscillators where their frequencies coincide. For example, let us assume that the crystal is 5 mc. The variable

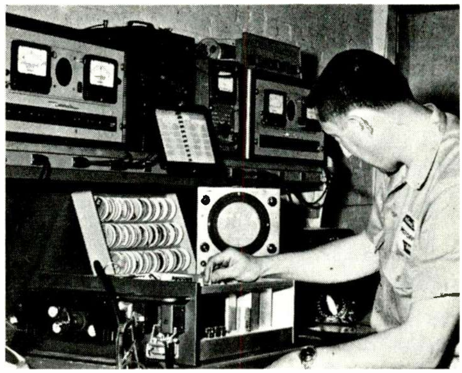
In Addition to Monitoring a Desired Channel, the Motorola Monitor Measures Transmitter Frequency and Deviation.

oscillator has a check point at each megacycle. At 1 mc its fifth harmonic is 5 mc and a zero beat is detected when the oscillator is adjusted to exactly 1 mc. At 2 mc the oscillators have a common harmonic frequency at 10 mc to provide the zero beat. At 3 mc the common harmonic is 15 mc, and so on. Harmonic beats are thus heard throughout the range of the variable oscillator.

Now let us suppose that we require a frequency check of a transmitter operating at a frequency of 39.97 mc. The variable oscillator is first calibrated against the crystal oscillator at 40 mc, the closest check point. The two internal oscillators are applied to the mixer, with the variable oscillator dial set at exactly 40 mc. A small calibrating control is now adjusted for zero beat. The oscillator is now at 40 mc and, because 39.97 mc is very close to this check point, the measurement at 39.97 mc will be very accurate. (The further the frequency being measured is removed from a check point, the greater will be the chance for error.)

Where the frequency range of the instrument is lower than the frequency of the carrier being measured, the harmonics of the variable oscillator will provide the necessary beat signal.

In figure 3B, a variation of the basic system of figure 3A, two separate oscillators (one crystal controlled and one variable) are combined to produce the heterodyning signal. By using harmonics of the crystal controlled oscillator, and combining the output of both oscillators, the instrument supplies an accurate signal at the desired frequency.



Besides Measuring Transmitter Frequency and Deviation, the Motorola Frequency Meter may be used as a Generator for "Netting" Receivers.

One of the inherent advantages of this instrument is the frequency stability of the crystal oscillator, which determines to a considerable degree the stability of the output. The harmonic amplifier provides signals at 1-mc intervals throughout the operating range of the instrument. The low-frequency oscillator is variable from 1 mc to 2 mc. By combining these two signals, then, we have an output which is continuously variable. (This variable oscillator is readily calibrated at 1 and 2 mc by beating it with the crystal oscillator.)

The harmonic amplifier is tuned so that the output at the desired harmonic is maximum. In addition, the dial (used for tuning for this maximum output) is calibrated according to the frequency generated in the mixer, thus providing an indication of the "megacycle" portion of the signal. The "kilocycle" portion of the output is determined from the calibrated dial of the variable oscillator, also calibrated according to the frequency produced at the mixer.

The heterodyne type of frequency measuring instrument (figures 3A and 3B) may also be used as a signal generator. The desired frequency is selected on the instrument and the output is taken from the "input" terminals.[2]

Deviation Meters

Deviation meters are basically highly calibrated FM receivers; the output from the detector must be a function of the amount of deviation and this output must be indicated on a meter. If the meter reading should change with variations of input signal strength, or with the gain of the receiver, the indicated deviation will not be accurate.

The method used for converting the carrier frequency to the operating frequency of the discriminator is unimportant when measuring deviation, as the amount of deviation is not altered by frequency conversion. If we are to establish an accurate indication of the deviation, however, two things are essential.

First, the output of the discriminator must be a function of the amount of deviation but not of the strength of the signal. If the output of the discriminator should change with signal strength, we do not have a reliable indication. By providing full limiting in the receiver for all incoming signals, the discriminator will respond only to frequency changes.

Second, the gain of the amplifier stages between the discriminator output and the indicator must remain constant. Usually one or two stages of amplification are required, and if the gain of these stages changes, the meter reading is not reliable.

The metering circuit for indicating the amount of deviation may respond to the peak deviation or it may respond to the average deviation. It is important for the serviceman to know the characteristics of his instrument if he is to use it intelligently.

Interpolating Vernier Dials

Many heterodyne type frequency meters are equipped with vernier dials, which provide accurate readings to five figures. A typical arrangement is shown in figure 3C.

The system is as follows. The first two digits (hundreds) are found on the hundreds dial. Here

2. See Test Methods, section 2, pages 36-38 and section 3, pages 11-14.

The Motorola Transistorized AC Voltmeter Will Measure Small AC Voltages Accurately and is Very Useful in Trouble Shooting Low Level Audio Circuits.

the reading is 3900, because the reference line is between 39 and 40.

The next two digits (units) are found on the inside circular dial. The marker for this dial is the zero reference line on the outer scale, which is between 27 and 28, so the next two digits are 27. The first four digits are 3927, and it remains only to read one more digit (tenths).

This final digit is read on the tenths vernier (the outer circular scale marked from 1 to 10). Whichever line of the vernier that coincides with (or is closest to) a line on the inner dial becomes the fifth digit. In figure 3C, the 33 on the inner scale is next to 7 on the vernier scale, so the final number is 7, and the complete number is 3927.7.

The ultimate accuracy of a vernier reading is always subject to a certain amount of "backlash." No matter how well the mechanism is constructed, there is always some backlash present and the readings can be expected to vary, according to whether the dial was rotated from a higher setting or from a lower setting. While the instruction book for any instrument should be followed in detail, it is customary to approach a setting from the low-frequency side and for the dial to have at least one full turn.

Once the dial reading has been determined, it must be converted to the corresponding frequency. A conversion chart is furnished with the instrument, but it is often arranged in 1-kc steps and does not include the in-between frequencies. It thus becomes necessary to interpolate the readings in order to obtain the exact frequency.

Suppose, for example, that the conversion chart indicates a frequency of 2420 kc for a dial reading of 3934.9, and 2419 kc for a dial reading of 3926.8. The dial reading of 3927.7 in figure 3 thus represents a frequency somewhere between 2419 and 2420 kc. The difference between the two dial readings shown on the chart (3934.9 and 3926.8) is 8.1. The actual dial reading (on the meter) is 3927.7, or 0.9 higher than the chart reading, which represents 2419 kc. The value 0.9 is only 1/9 the total difference (8.1); hence, the frequency difference is 1/9 of 1 kc, or 111 cycles. Adding this to 2419 kc, the frequency is found to be 2419.111 kc.

Some dials may differ slightly from the one shown in figure 3C, but the system of interpolating the reading remains the same.

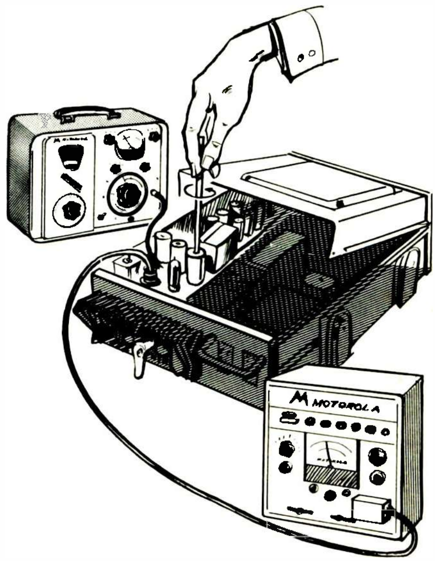
AC Voltmeters

The AC VTVM is another important instrument in the servicing of two-way equipment. The ordinary VTVM is usually not satisfactory because its range is not low enough to provide accurate readings for small AC voltages. Besides having a high impedance, the AC meter must be capable of indicating small voltages in order to be useful to servicemen.

Microphone and other audio devices often have outputs of less than one volt, and it is essential to have an accurate means of measuring such voltages.[3]

We see from the above that the low scale of the meter should require no more than 1 volt for full-scale deflection. The manual for a particular 450-mc base station, for example, may state that the input level is 0.10 volt. Unless the scale used is at least as low as 1 volt, the meter deflection will not be sufficient to measure this value accurately. (The newer Motorola test set, Model TU546, provides for low-level AC voltage measurement facilities.)

A sensitive oscilloscope can be used instead of the AC voltmeter, and the scope can be accurately calibrated. Its limited portability is generally objectionable, however. While not essential, it is always convenient for the AC voltmeter to be portable, as the serviceman must often use this instrument where no AC power is available.



A Signal Generator and the Test Set are Recommended for Aligning Motorola Receivers.

Wattmeters

One of the most practical instruments for the service and maintenance of two-way equipment is the wattmeter. This instrument is valuable not only for aligning and trouble shooting the transmitter; it can be used also for trouble shooting the antenna system.

Wattmeters are of two general types. One type is terminated in a specific load which matches the impedance of the antenna system, the meter being used to measure the amount of power delivered to

3. See Test Methods, section 2, pages 11-18.

that load. The other type uses the antenna system as the load and merely measures the power being transferred from the transmitter to the antenna. This type of wattmeter can be used to measure both forward and backward power. That is, the meter will indicate the amount of power returning from the antenna to the transmitter as well as the power being delivered from the transmitter to the antenna.

Wattmeters indicate the power directly when they terminate in a dummy load. It is important, however, (1) that the terminal impedance be matched to that of the antenna system--namely 50 ohms, (2) that the range of the meter include the transmitter frequency, and (3) that the power rating of the meter be adequate for the equipment being measured.

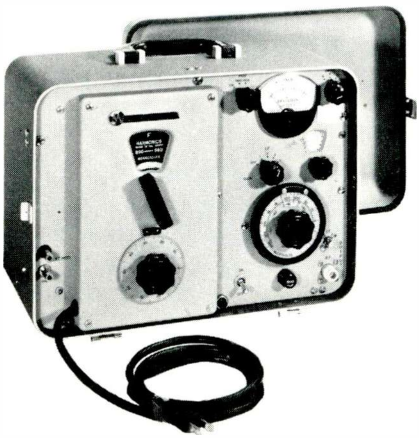
The Motorola test set may be used in conjunction with the Motorola dummy antenna in order to measure RF power. The dummy antenna includes a rectifier and meter calibrating resistor, which are used for measuring the current. Conversion tables are then consulted to determine the corresponding RF power.

By knowing the amount of power being delivered to the load, it is possible to adjust the transmitter for maximum output. Since the antenna has the same impedance as the dummy load, the tuning procedure does not change and the final settings will be the same when the antenna is substituted for the wattmeter and load. If the antenna is not perfectly matched to the transmitter, however, the settings may have to be changed when the antenna is substituted for the dummy load.

The wattmeter, when placed directly in line with the antenna, depends upon the antenna itself for the load, and it often proves to be a valuable instrument not only for checking the efficiency of the antenna system, but for measuring the RF power output of the transmitter as well.

This type of wattmeter is capable of measuring the amount of RF power reflected from the antenna to the transmitter as well as the amount of power delivered from the transmitter to the antenna. The difference between forward and backward power furnishes an indication as to whether the power reaching the antenna is actually being radiated into space as a radio wave, or returned from the antenna to the transmitter. This illustrates the importance of maintaining correct impedances. Unless the proper impedances are maintained, the power cannot be radiated by the antenna and must return to the source. If the impedance mismatch is as much as 2 to 1, the power loss is 11 per cent.

When measuring antenna power, the possibility of transmission line losses must also be taken into consideration. Suppose, for example, that the meter is placed between the transmitter and the transmission line. Any forward power indicated on the meter will represent the actual power being transferred to the antenna. The reflected power reading, however, may not show the true picture, for the reflected power reading is affected by the power loss in the transmission line, both going to the antenna and returning in the line to the transmitter.



This New Motorola Signal Generator Covers All the Frequency Bands Used for Two-Way Communications.

Let us further suppose that the transmission line in the above example offers a total loss of 6 db at the operating frequency and that the power available at the transmitter is 100 watts. With a 6-db loss in power (a power ratio of 4 to 1), the power reaching the antenna will be only 25 watts. Now let us suppose that the antenna is not properly matched and that only half of the power reaching the antenna (12.5 watts) is radiated, the other half (12.5 watts) returning from the antenna to the transmitter. This means that the reflected power at the antenna is 12.5 watts. but only one-fourth of this power reaches the transmitter, for again there is a 6-db loss and the reflected power at the meter is more than 3 watts. The meter at the transmitter thus indicates that the forward power is 100 watts and that the reflected power is 3 watts. Disregarding any loss in the transmission line, it would seem that the antenna system was satisfactory. On the contrary, however, the true story can be found only at the antenna end of the transmission line. A wattmeter at this position will show that the forward power is only 25 watts and that the reflected power is actually 12.5 watts--a very undesirable condition.

The cause of the above condition is twofold. For one thing, the antenna is not proper, as indicated by the high percentage of reflected power. For another thing, the 6-db loss of power in the transmission line indicates that the line is at least improper--if not actually defective--and that a different type of line, one that does not have so much loss, should be used.

Signal Generators

The RF signal generator which has an accurately calibrated output can be one of the most practical among the various measuring and trouble-shooting instruments used by the serviceman working on two-way equipment. This instrument is not essential as far as FCC requirements are concerned, but it is very convenient for checking the operation of a receiver.

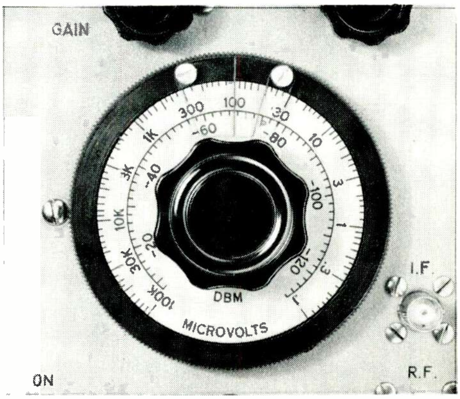
The Motorola test set is accurately calibrated for IF alignment when a 455-kc crystal is used. Hence, the frequency calibration of the RF signal generator is not as important as its indication of the output signal level. Sensitivity is one of the primary considerations of the communications receiver; without a signal generator to determine the 20-db quieting level, it is hard to tell when the receiver is working at its full rating.

By using a generator (such as the Motorola TU576, or equivalent) together with an output indicator for the receiver (the Motorola test set provides this function), the sensitivity of the receiver can be measured in a very short time. This arrangement is very helpful both in alignment and in trouble shooting.

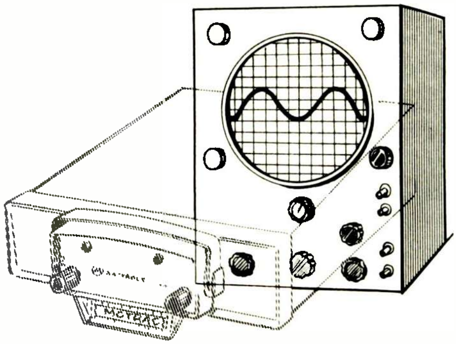
When aligning the receiver, the generator conveniently provides an RF signal having a predetermined level. The Motorola test set then indicates the output for the various circuits and the latter are adjusted to any level required. After all circuits have been adjusted, the RF level of the generator will indicate the exact sensitivity of the receiver.

When trouble shooting the receiver, the generator provides a substitute signal, and the frequency and level of this signal may be varied as required. Stage gain measurements can thus be made by the serviceman in order to determine the operation of each section of the receiver. (If the serviceman knows the amount of input voltage which is required in order to produce a specified output voltage for a particular stage, the exact location of a defective section can be easily determined.)

When using the signal generator with a receiver, it is important to provide the proper impedance match. Otherwise, the voltage indicated by the generator will not be accurate; measurements will be meaningless. This readily accounts for differences in readings when several generators are used. Unless the generator is properly terminated and unless the correct cabling and termination is provided, valid measurements cannot be obtained.



Here We See the Level Adjusting Dial of the Signal Generator. The Setting Accurately Indicates the Generator Output Voltage.



A Scope is Very Useful in Adjusting the IDC Circuit and Trouble Shooting the Audio Section of the Transmitter.

The accuracy of the output voltage furnished by the signal generator can be completely nullified if there is an appreciable amount of leakage RF. It will be obvious that a generator which radiates more signal into the receiver than that provided at its output terminals would be nearly useless at low signal levels.

The range of the instrument should include all frequency bands for the equipment being serviced --ideally from 5 mc to 1000 mc for equipment used in two-way communications. While few present-day receivers operate in the 900 mc band, it is probable that more receivers will use these high-frequency channels in the future. This frequency setting need not have a high degree of accuracy, it is true, but it is essential for the generator to have good frequency stability. The low-frequency range also finds no direct use as a channel frequency, but the 5-1000 mc generator provides the necessary output often required when aligning the high-frequency IF sections of receivers.[4]

Oscilloscopes

While the "scope" cannot be regarded as an essential piece of test equipment (since service work can be performed without one), its versatility makes it an invaluable instrument in all kinds of service work.

The scope is capable of indicating and measuring almost any electronic factor that is usually measured by a meter (frequency, waveform, phase, amplitude, etc.). It is particularly convenient when used in conjunction with a deviation meter. While any of the deviation meters discussed in this lesson can be used to indicate average or maximum deviation, it is not possible to record both values on the same instrument, nor is it possible to determine the exact modulation pattern being measured. The scope, however, indicates the actual waveform of the signal, and when it is calibrated according to its vertical deflection, the exact peak deviation is indicated. Furthermore, oscilloscope patterns for the voice range are entirely independent of frequency. When used in connection with the operation of the transmitter IDC circuit, the scope will indicate the exact point of clipping and the operating waveforms.

While the average serviceman is acquainted with the general op-

4. See Test Methods, section 2, pages 61-68.

eration of this instrument, it may be well to review the basic circuit. Figure 4 shows the functions of the various sections of a typical model.

The scope is designed about the cathode ray tube (CRT). Deflection plates in the CRT allow the electron beam to be bent vertically and horizontally, and a waveform is thus produced according to the nature of the deflecting voltages applied to these plates.

The horizontal deflection is normally a sawtooth wave wherein the beam is gradually pulled from the left-hand side of the tube to the right. When the beam reaches its extreme right excursion the waveform changes, returning it very quickly to the left-hand side. The cycle is then repeated continuously. The horizontal deflection plates in figure 4 are connected to the output of the horizontal deflection amplifier. The amplifier input comes from the sweep (sawtooth) generator and its frequency is variable. This sweep waveform is triggered by the vertical section when the sync selector switch is at INT. A small portion of the vertical deflection voltage is then applied to the horizontal generator in order to synchronize the horizontal sweep frequency with the frequency of the vertical voltage.

The desired waveform is applied to the vertical amplifier and the output impressed upon the vertical deflection plates. Gain controls are provided for both vertical and horizontal deflection voltages, and the pattern may be shifted either to the right and left or up and down, by the two positioning controls, R3 and R4.

The exact manner in which the waveform is produced on the CRT screen is thoroughly explained in other publications and need not be repeated here. We are interested, rather, in the practical use which can be made of the waveform thus produced.

By knowing the nature of the waveform applied to a circuit, and then comparing it with its successive representations as it passes through the various stages, the operation of these stages can be evaluated, particularly with respect to gain and distortion.

In the audio section of the transmitter, the waveform of the audio modulating voltage is of particular interest, for the entire purpose of this section is to control the amplitude and waveform of the voltage applied to the modulator. By observing the waveform at successive stages within this section, operation of each portion of the circuit can be evaluated and any inoperation or malfunction immediately pinpointed. Moreover, the vertical deflection can be plotted against vertical input voltage, which enables the serviceman to ascertain the various levels of audio voltage from point to point within the circuit.

Typical audio waveforms within the transmitter are shown in figure 5. The left-hand column shows waves produced as a result of clipping, at various voltage levels. The right-hand column shows the resulting waveforms, respectively, at the output of the integrator. The upper waveforms show no change from the original sinewave, which means that the amplitude is not sufficient to cause clipping, and the sinewave is not altered by the integrator. The lower waveforms show what happens when the input voltage is very high. The severe clipping of the wave produces a square wave output and the integrator changes the square wave into a triangular wave. The waveforms in between these two extremes represent various degrees of clipping.

Distortions within the audio section of the receiver are readily located by means of the scope, and they can be quickly pinpointed with this instrument to a definite section. This is done by putting the input audio signal on the scope and then following it through the circuit. Any deviation in the original waveform indicates some kind of distortion.

Since the exact signal level can be determined by means of the scope calibration, the instrument thus becomes a sensitive AC voltmeter. By comparing the input amplitude of a stage with the output, the stage gain can be determined. Coupling circuits may show a high degree of attenuation from the plate of one stage to the grid of the next stage, automatically indicating a defective circuit. Open coupling capacitors are readily located by this method although they cannot be discovered by means of voltage or resistance tests. When checking coupling circuits, the serviceman must remember that some attenuation will always be encountered, and that it will be greater at the lower frequencies than at the higher frequencies, resulting in a proportionally greater loss. This is particularly true where the coupling capacitance is relatively small.

The scope finds good use in connection with the Motorola Monitor in measuring deviation. Test calibration circuits in the instrument allow a quick calibration of the vertical deflection at 15 kc, and the gain of the scope can be adjusted for a convenient deflection at 15 kc. The gain of the scope can then be adjusted for a convenient deflection with this known voltage applied. Then, when a signal is applied to the instrument, the amount of deviation can be immediately determined by means of the deflection produced. Observation of the waveform shows both peak and average deviation.[5]

The Test Bench

Figure 6 shows a practical test bench which includes the test equipment necessary for properly servicing two-way radios. On the

5. See Test Methods, section 2, pages 40-53.

upper shelf from left to right we have the Motorola frequency and deviation meter, the Motorola transistorized AC voltmeter, the Motorola test set, a dummy antenna, an RF wattmeter, and the Motorola Signal Generator.

Other test equipment includes a power supply for bench operation of mobile radios, a filter for operating transistorized receivers, a meter panel which allows for simultaneous monitoring of the various receiver circuits, and battery testers.

On the work shelf we see a typical two-way radio, this particular model being a "Motrac" unit, which includes a completely transistorized receiver and power supply. Additional tools, cables, service manual, etc., may be kept in the storage areas below.

STUDENT NOTES

STUDENT NOTES

STEP 1
CALIBRATE 5MC CRYSTAL OSCILLATOR WITH WWV

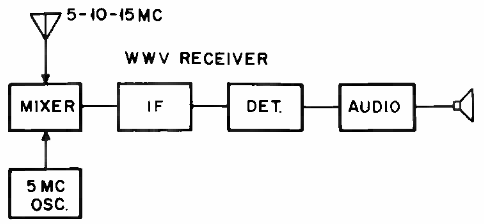


FIGURE 1A

STEP 2
USE 5MC OSCILLATOR TO CALIBRATE THE CONTROL RECEIVER TO 150MC

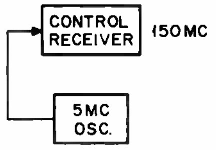


FIGURE 1B

STEP 3
DETERMINE THE CORRECT CRYSTAL FREQUENCY

152.5 (CHANNEL FREQ.)
-150. CONTROL RECEIVER
2.5 MC

FIGURE 1C

STEP 4
WITH CORRECT CRYSTAL IN OSCILLATOR, APPLY OSC. AND RF SIGNAL BEING MEASURED TO MIXER. MIXER OUTPUT IS APPLIED TO CONTROL RECEIVER AND DISCRIMINATOR OUTPUT INDICATES FREQUENCY OF RF SIGNAL

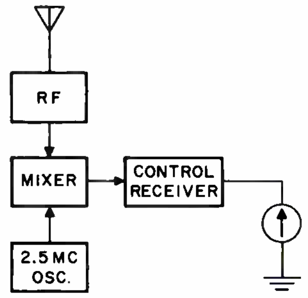


FIGURE 1D

FREQUENCY MEASUREMENTS
USING THE MOTOROLA MONITOR
FIGURE 1

STEP 1
ADJUST AUDIO OUTPUT TO SPECIFIED READING ON DEVIATION METER

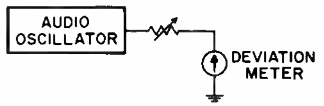


FIGURE 2A

STEP 2
ADJUST AUDIO GAIN FOR 15KC DEVIATION

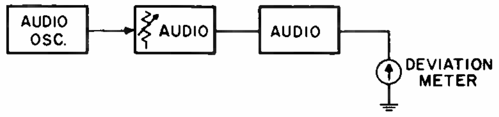


FIGURE 2B

STEP 3
READ DEVIATION ON METER

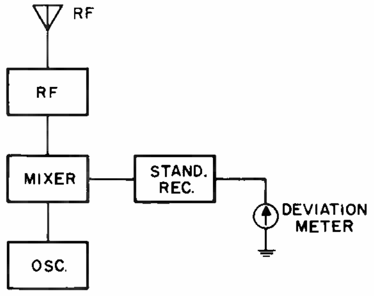


FIGURE 2C

USING THE MOTOROLA MONITOR
TO MEASURE DEVIATION
FIGURE 2

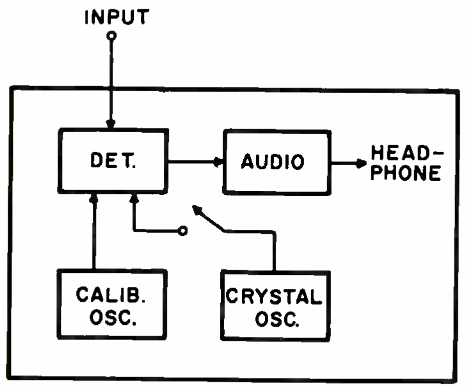


FIGURE 3A

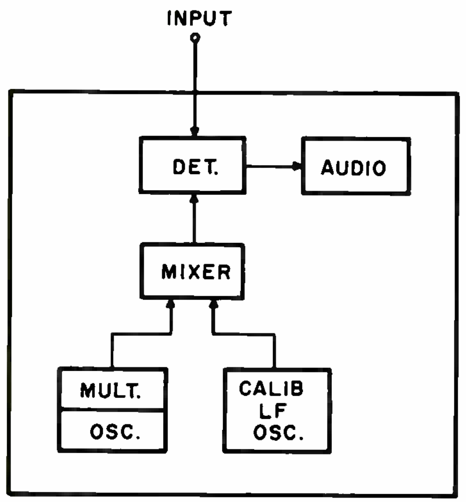
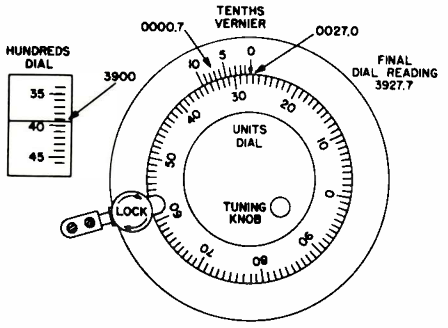


FIGURE 3B

HETRODYNE METERS



DIAL OF A TYPICAL HETERODYNE
FREQUENCY METER

FIGURE 3C

STUDENT NOTES

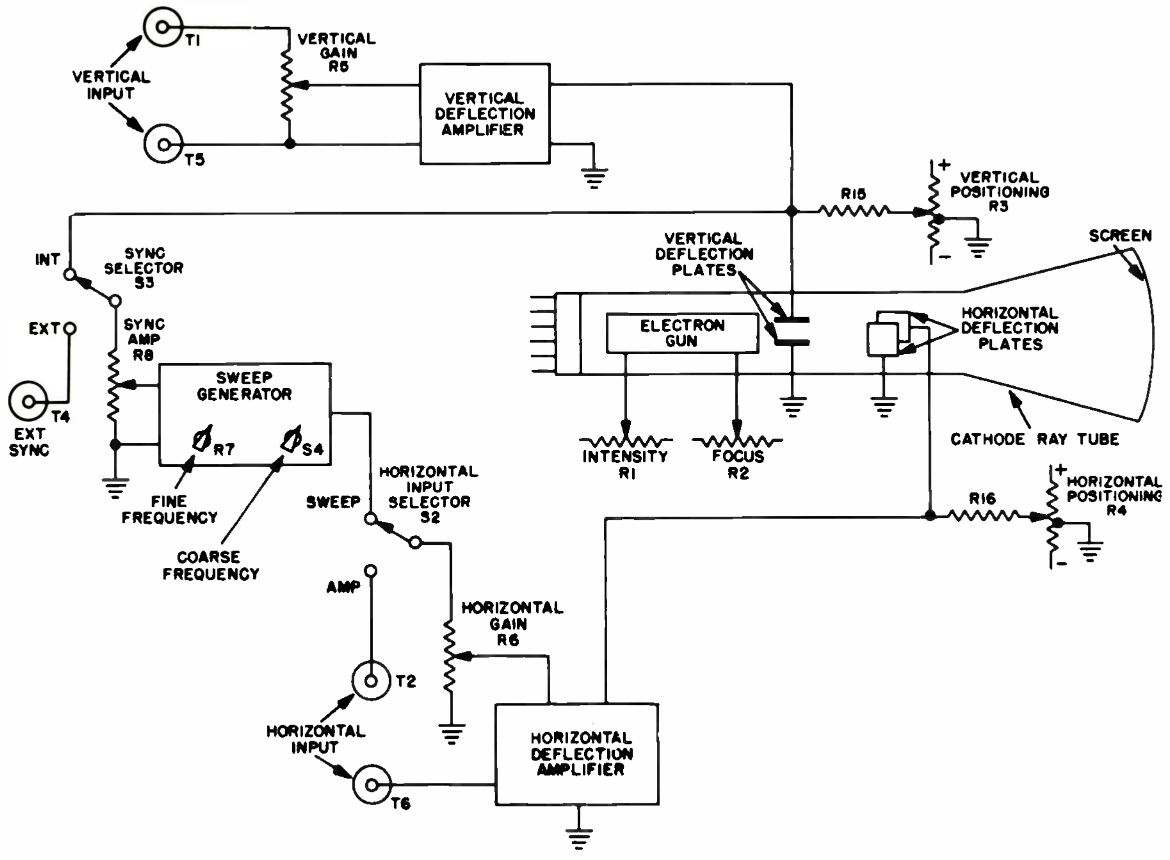
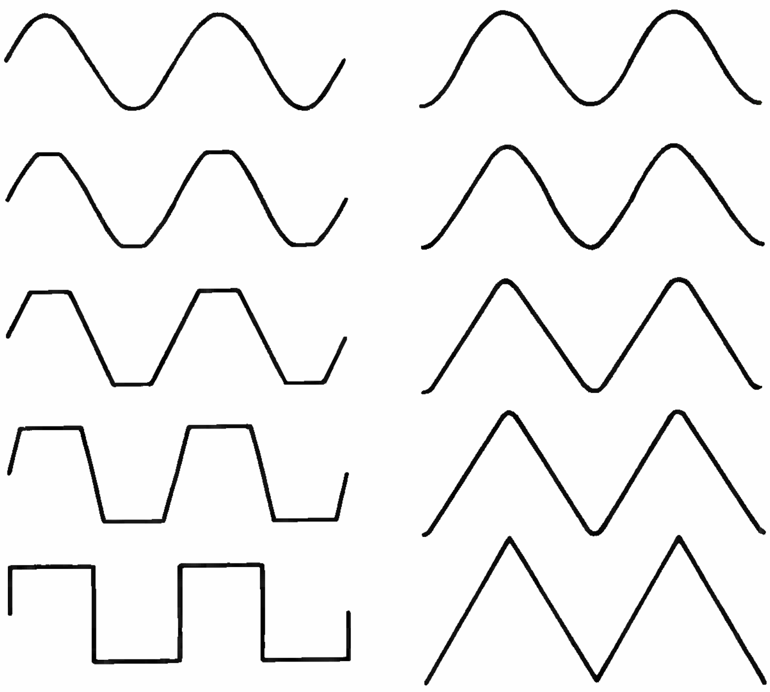


FIGURE 4



SINE WAVES WITH VARIOUS DEGREES OF CLIPPING, BEFORE AND AFTER INTEGRATING

FIGURE 5

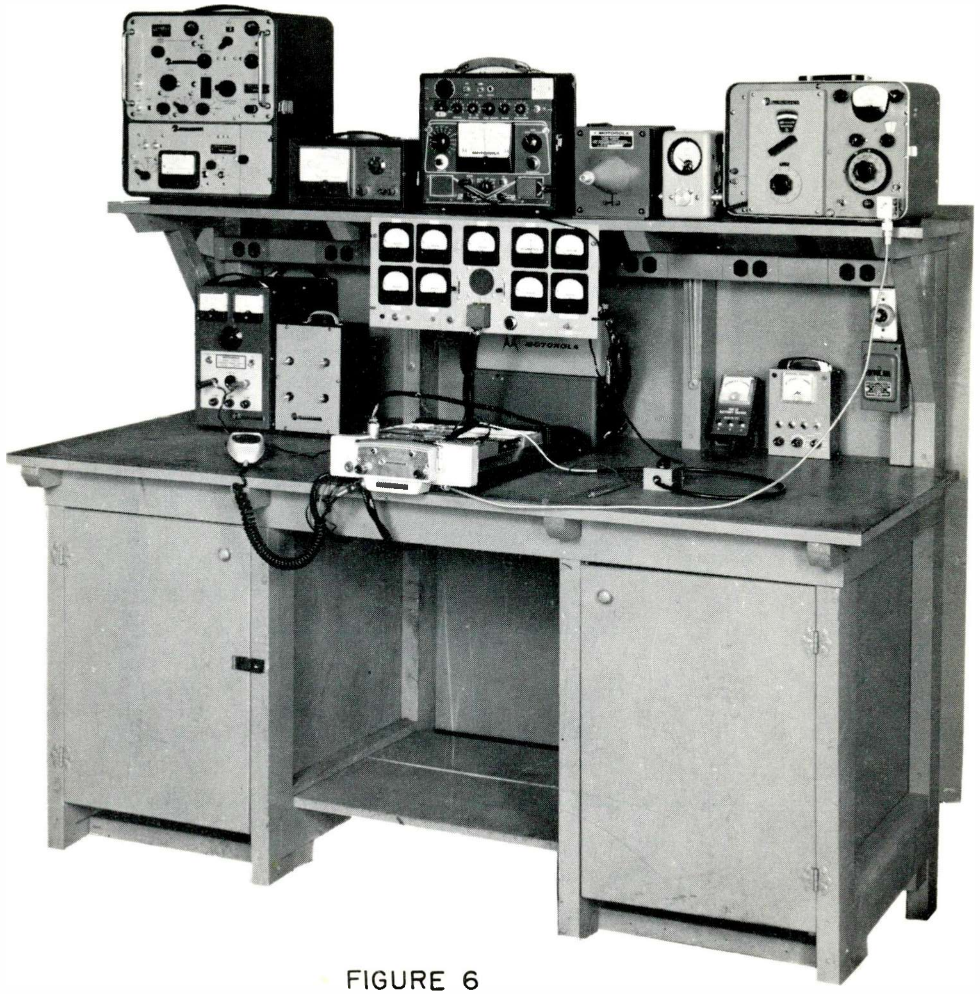


FIGURE 6

national

MOTOROLA

RADIO COMMUNICATIONS

service

A TWO-WAY RADIO COMMUNICATIONS TRAINING PROGRAM

LESSON MA-6
MAINTENANCE

Transmitter Servicing

MOTOROLA TRAINING INSTITUTE

TRANSMITTER SERVICING

Lesson MA-6

TABLE OF CONTENTS

NOTICE

Diagrams and figures referenced in text are "fold-outs" in back of each lesson, for use while studying. The Examinations are also there.

One Business Radio Service user is the company specializing in tire service. Large wheels on modern trucks and farm equipment need special handling tools. With radio, firms so equipped are able to provide special service.

A TWO-WAY RADIO COMMUNICATIONS TRAINING PROGRAM

LESSON MA-6
MAINTENANCE

Transmitter Servicing

—one of a series of lessons on two-way FM communications—

MOTOROLA TRAINING INSTITUTE
4501 W. AUGUSTA BLVD., CHICAGO 51, ILLINOIS
APPROVED BY THE STATE OF ILLINOIS
DEPT. OF REGISTRATION AND EDUCATION

PREFACE

This is one lesson of a complete Motorola Home-Study Course which presents to the Service Technician both the principles of operation and the maintenance of two-way FM radio systems. The program covers mobile, portable and base station equipment, including the latest transistorized units.

TRANSMITTER SERVICING
Lesson MA-6

Introduction

In this lesson we shall discuss various techniques for servicing FM transmitters used in two-way communications. We shall proceed in the following order: (1) identification of a fault, pinpointing it to a particular section of the transmitter, (2) location of the specific trouble, and (3) correction of the trouble.

We shall be using the high-band transmitter shown in figures 1 and 2, but the trouble-shooting techniques applied to this unit will work equally well with other transmitters, particularly with the low-band units. Toward the end of the lesson, we shall discuss problems which apply only to certain specialized equipment, such as 450-mc transmitters.

Determining the Exact Trouble, Using the Motorola Test Set Only

When using the Motorola test set only, the serviceman will follow test procedures which are different from those he would use if he had more test equipment available. To start, let's assume that he has only the Motorola test set, and that the fault is definitely in the transmitter--both the antenna system and the power supply are normal.

RF Output

The first step when trouble shooting any transmitter is to observe the reading in the PA position of the test set. If this reading is high, the HI-LO switch must be placed in the LO position. Now observe the readings of test set positions 3, 4, 5, and 6 to get an over-all idea of the transmitter operation. If an intelligent appraisal is to be made, these readings must be compared both with the recommended values and with the values previously recorded for the transmitter, when it was operating normally.

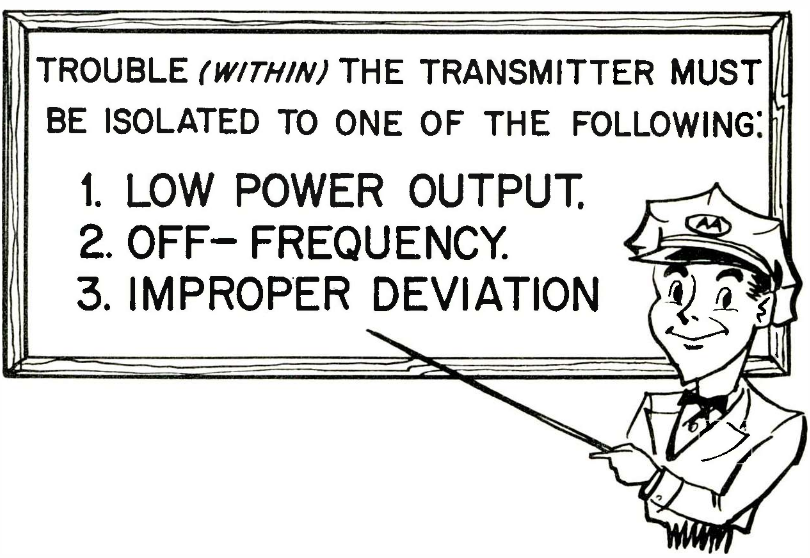
The meter readings with the test set in positions 3, 4, 5, and 6 are used to check the preceding stages. Thus, if the reading at position 3 is normal, we know that the RF level at this point is normal. That is, the oscillator, modulator, buffer-doubler, and tripler input circuit are all operating as they should. (The frequency may be incorrect, but at this point in our procedure we are interested only in the amount of RF.)

The reading at position 4 checks the operation of the tripler stage and the input to the second doubler. If the reading at 4 is normal, try position 5. If the reading is still normal, proceed to position 6.

How do these meter readings help isolate the trouble? Let us suppose that the readings at positions 3 and 4 are normal, but that the readings at 5 and 6 are low. This tells us that the trouble is in either the second doubler or the input of the driver stage. The logical procedure is to try new tubes in these stages and to check the readings again. If normal readings are now obtained, merely touchup the alignment and your unit will be ready for use. If the readings are still low, however, more detailed trouble shooting will be required in these stages.

As another example, let us assume that all the readings are zero, or at least very low. (The reading at position 6 is never zero so long as the bias supply is applied to the grid circuit of the PA stage.) This means that the trouble is in one of the first three stages (oscillator, modulator or buffer) or that it is in the input to the tripler stage. Again the logical procedure is to try new tubes in these stages. (Try another crystal in the oscillator, too, if a suitable one is available.) If this procedure fails to correct the condition, further trouble shooting will be required.

When the reading at all positions (3 through 6) are normal, the next problem facing the technician is to determine if there is an RF output; and if so, to determine its approximate power.



In Trouble Shooting the Transmitter Be Sure to Identify the Specific Trouble to be Corrected.

The meter positions provided in high-band and low-band transmitters do not show RF power output. The reading at position PA is an indication of the DC plate current only and is no guarantee of RF power. Only when the complete alignment procedure of the final tank, coupling and antenna circuits are followed, with normal results, can we be reasonably sure that the reading at the PA position shows the presence of RF power in the antenna. The test set responds to RF signals when used as a field strength meter, but it does not indicate the frequency or the amount of output.

Measuring Power Output

As we have just seen, measuring the power output of the transmitter becomes a problem when all the serviceman has available is the Motorola test set. If he is to provide quick and accurate service, he should be equipped with some means of actually measuring the RF output at the transmitter. Either a wattmeter or the Motorola dummy antenna (used with the test set) will serve this purpose.

Several types of wattmeters are available. Any type will suffice for determining the power output of the transmitter as long as it is reasonably accurate at the frequency involved. Using the Motorola dummy antenna, relative readings can be taken on the test set and the power can be accurately determined by means of the charts supplied. These instruments are easy to use when it is desired to measure the carrier power quickly. From the standpoint of isolating the trouble, the serviceman, as soon as he knows that the power output is normal, can concentrate on the operating frequency, the modulation, or any other faults that might exist within the transmitter.[1]

Even though the RF power output of a transmitter is known to be relatively normal, the transmitter itself may not be operating normally because (1) the carrier frequency is not on channel, or (2) the modulation is nonexistent, or at least very low.

Operating Frequency

The possibility that the carrier is off channel can be detected by means of a monitor receiver of known calibration, or by means of a frequency measuring device. If neither of these is available, the serviceman will be unable to determine the operating frequency of the transmitter.

Modulation

Metering facilities are not provided in the transmitter for measuring either the modulation or the audio input to the modulator. The newer TU546 test set, however, allows the audio voltage to be measured at the microphone, and this tells the serviceman that there is audio in the transmitter.

1. See Test Methods, section 2, pages 29-31.

Additional equipment is required in order to check modulation.

Isolating the Trouble-- Monitor Receiver

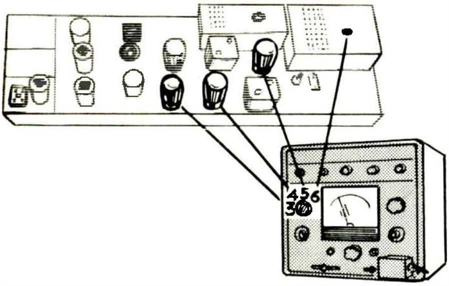
We have just seen how a fault is isolated within a transmitter when using only a Motorola test set. A monitor receiver can also be used for making a quick check if the technician has one available. (We must assume that the monitor receiver picks up signals from other transmitters within the system and reproduces them with normal clarity.) The first step is to open the receiver squelch so that some noise is heard. The transmitter is then keyed and any noise quieting in the receiver noted. If there is some quieting, a carrier is present, although it may be weak or slightly off channel. The off channel factor is immediately checked by observing the test set reading at the discriminator secondary--it should be near zero. Although it is not advisable to adjust the transmitter frequency according to the reading on the receiver discriminator, this reading provides a good check on the approximate carrier frequency.

The monitor receiver also provides a check on any modulation taking place in the transmitter. If the carrier provides a reasonable amount of quieting in the receiver and if the carrier is reasonably close to the correct frequency, the receiver output will indicate the presence of modulation, whether weak, normal, or overdeviated. The receiver, however, will not give an accurate indication of the modulation if the carrier is too far off frequency. Again, the monitor receiver is not to be used to adjust the modulation of the transmitter; it merely gives the serviceman a relative idea of what is taking place. It enables him to quickly ascertain if there is trouble within the transmitter, and if it is one of the areas checked.

We have learned thus far how to isolate the trouble in a transmitter, pinpointing it to some particular stage or section. Once this has been done--and if the fault is not readily corrected by some simple adjustment or a replacement tube--it will be necessary to further analyze the faulty stages of the transmitter. In many instances the transmitter must be removed and placed on the test bench for this more complete analysis.

Trouble Shooting the Oscillator

Voltage and resistance readings, such as those shown in figure 1 for the 10-watt transmitter, are helpful in locating a defective component. This particular transmitter also provides for monitoring the oscillator activity (test meter position 2). The minimum reading is 10, but it will be higher than this in most cases. If the reading should drop below 10, however, the oscillator should be watched both for activity and for frequency.



Test Set Measurements Help to Quickly Isolate "Low Output" Trouble to a Specific Stage of the Transmitter.

While the test-set reading at position 2 can be taken as an accurate indication of the amount of oscillator activity, it does not tell us how well the plate circuit of the oscillator operates, nor does it tell anything about the signal applied to the modulator or to the buffer-doubler. This information can best be obtained by measuring the voltage at the buffer grid, which is a good indication of the signal level. In figure 1, the voltage at the buffer grid is 2.5 volts negative. This serves, then, as an indication of the RF level, which is the output from the oscillator-modulator section. A VTVM equipped with an RF probe will also indicate the presence of RF. The probe may be used at the plate circuit of the oscillator and at the grids of the modulator and buff-doubler stages to determine the RF level at these points.

Low RF output from the oscillator may be caused by low supply voltages resulting from resistance changes in the plate and screen dropping resistors, open or leaky capacitors, a weak tube, or a poor crystal. In most instances a voltage and resistance check of the circuit and its components will reveal the defect, but occasionally it may be necessary to substitute new units and compare the results.

The Modulator

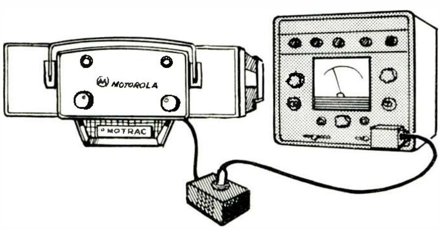
The modulator is basically a low-gain RF amplifier stage in which provision is made to phase modulate the RF signal in the output. The DC grid voltage is zero with respect to ground, and bias is supplied by a cathode resistor. Trouble shooting is accomplished by means of (1) voltage checks, (2) resistance checks, and (3) tests performed on the individual components.

Modulation deviation and linearity is determined to a considerable extent by the operation of the stage. It is therefore important to keep the voltages near their nominal values.

Looking at the schematic, we see an electrolytic bypass capacitor at the cathode. Its bypass quality may be poor without seriously changing the DC operating voltages. At the same time, however, the modulation characteristics of the stage could be poor; the modulation may be weak as well as distorted.

The Buffer-Doubler

The buffer-doubler is basically an RF amplifier which provides an output at twice the frequency of the input signal. The grid voltage is due both to the oscillator output and to the signal from the modulator. To provide good modulation linearity and a stable carrier frequency, the stage is operated with Class B_2 bias rather than Class C. (Class B_2 indicates operation near cut-off, with the grid driven positive by the signal.) Before performing any detailed trouble shooting, the serviceman should make sure that the grid drive (voltage) is correct.



The Motorola Test Set and Dummy Antenna may be Used to Measure Transmitter Power Output.

Figure 1 shows no metering facility for the buffer-doubler, but the grid drive is checked by reading the negative grid voltage, which should be at least 2.5 volts for this particular transmitter. This grid voltage controls, to some extent, the voltages at the other tube elements. The action is as follows: The grid bias voltage limits the amount of plate current, and the plate current establishes voltage drops across the various resistors in the circuit. If the plate current increases, the voltage across the plate dropping resistor (R1) also increases, causing a lower potential at the plate. At the same time, the increased plate current through the cathode resistor increases the cathode voltage.

With the proper signal applied to its grid, the operation of the buffer-doubler stage may be determined by the reading at the grid of the following tripler stage (position 3). The maximum voltage at position 3 will be obtained only when the interstage transformer is peaked. This transformer has a tuned primary and a tuned secondary; as either is adjusted to resonance, a sharp maximum reading should result. If either the primary or the secondary fails to show a satisfactory peak, the circuits will not be properly tuned.

Tripler, Doubler and Doubler-Driver

These three stages all operate in much the same manner. As Class C amplifiers and frequency multipliers, they increase both the power and the frequency of the RF signal. Trouble shooting procedures for all three stages are essentially the same as that described for the buffer-doubler.

The RF output of each stage depends primarily upon the grid drive voltage. Therefore, the input signal to any stage must be normal before any further checks are made. The RF output of each stage is conveniently measured at the grid of the following stage. Each stage provides some reserve drive to the next stage. That is, the grid drive is more than the minimum amount needed to produce the required output. Thus, while the readings given in figure 1 are satisfactory, it is desirable to have more than this nominal amount in order to counteract the normal decreases that occur as the equipment ages.

These three multiplier stages incorporate pentode type tubes because they offer high gain with minimum drive. Screen voltages must be correct if full power output is to be realized. The screen voltage greatly affects the amount of plate current, and in a Class C amplifier or multiplier the power output is generally a direct function of the amount of plate current and the amount of grid drive.

It should never be necessary to make any change in the circuitry or in the value of a component in order to obtain correct drive voltages. If the recommended readings are not obtained, look for a defective component. Neither should interstage coupling be changed. Occasionally it would appear that the degree of coupling (between doubler-driver and PA, for example) could be changed by altering the relative position of the primary and secondary winding. This must not be done, however, for although it may seem that the amount of grid drive could thus be increased, this is not always the case.

The driver output (or the input to the PA) may increase in undesirable harmonics, but not in desired signal. The spurious emission may also exceed the maximum allowed. (The 450-mc transmitter is an exception to this rule, however. Here the interstage coupling is variable and must be adjusted according to the recommended procedure.)

Power Amplifier Problems

The various adjustments and alignments required in the PA stage make it one of the most critical sections of the transmitter. It is subject to more damages as a result of misalignment because of its high power level and its tubes are the most expensive in the transmitter. It is thus advisable to minimize tube replacement by making sure that they are always operating properly.

Plate current is controlled by the grid voltage, the screen voltage, the plate voltage and the plate tank, also by the antenna loading adjustments. To prevent the plate current from becoming excessive (in case the grid drive should fail), fixed bias is applied to the grid at all times. Moreover, a "High-Low" switch is usually incorporated in the screen grid circuit.

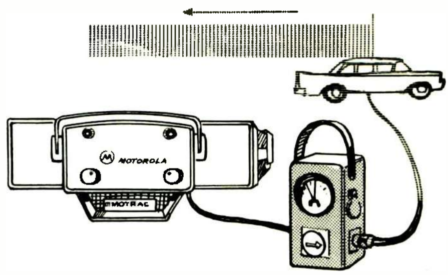
This switch permits lowering the screen voltage by inserting a higher resistance in the screen circuit when the plate circuit is not properly tuned. If the final stage is not operating properly, the switch is immediately placed at "Low" and left in that position until servicing and tuning are completed.

When the grid drive is normal, the stage is biased Class C. Unless the plate circuit is tuned to resonance, however, the current may still be too high; hence, the switch is left at "Low" until the plate tank is adjusted to resonance.

If the PA grid drive fails, the fixed bias will keep the plate current from rising beyond the safe limits for the tube. With no RF in the plate circuit, the tuning of the plate tank has no effect on the plate current--and there can be no coupling to the antenna if there is no RF present. With no RF power present, coupling adjustments will have no affect on the plate current.

Trouble is quickly pinpointed to either the grid circuit or the plate circuit by observing the meter readings at position 6 for the grid, and at the PA position for the plate. It can also be isolated by observing the peaks when the circuits are tuned through resonance. (When the final is loaded by the antenna, the plate current peak will be very broad.)

Voltage readings for the final stage will help to pinpoint any trouble to the defective portion of the circuit. Resistance readings are also very helpful, especially in locating resistors that have changed value.



If a Thruline Output Meter is Used, the Transmission Line Should Terminate into the Antenna.

Reduced RF output (assuming that the input is normal) may be caused by a weak tube, low supply voltages, improper tuning, a defective component, or any combination of these factors. Each possibility should be checked thoroughly in any logical trouble shooting procedure. If the grid drive is normal, the tube may be replaced by one known to be good and the results compared. The final tube will often show a slight "glow" around the glass envelope. A slight glow may be normal and does not necessarily indicate a defective tube or excessive current. In low-power transmitters (such as the 10-watt unit), the PA tube is less apt to show this glow than when this same tube is operated with higher voltages to produce power outputs of 25 watts or more. If the tube becomes gassy (or "soft," as it is often called), there will be a glow around its electrodes and this glow will extend over the greater portion of the tube. This will generally indicate a defective tube (low power output) and the tube should be replaced. Operating a tube beyond the recommended values of plate and screen current will often make it prematurely soft and shorten its life.

The Audio Stages

The audio stages in the transmitter of figure 1 are the audio amplifier and the clipper. Where transistorized microphones are used, the transistor amplifier must be considered as part of the audio section of the transmitter, even though the amplifier itself is mounted in the microphone housing.

Misadjustment of the "instantaneous deviation control" (IDC) can produce bad effects, both in the operation of the system and in the interference produced in other channels. Because of the great importance of this circuit, the serviceman must be careful to establish its proper operation and maintain a proper adjustment of the control (R130) at all times.

Once the input signal reaches a certain predetermined level, the output voltage no longer increases. By driving the diodes in the clipper stage to maximum plate current, the output voltage is limited in amplitude; stronger audio voltages cannot produce higher voltages from the clipper. In most transmitters the maximum input level without causing clipping is 0.18 volt at the grid of the amplifier (0.25-volt signal at the input if the tap at position 1 is used). Before proceeding to adjust the IDC control for the correct amount of deviation, the modulation sensitivity must be correct. That is, with 0.25 volt applied to the input, the peaks of the signal reaching the 6AL5 should be at the point of clipping.

To check the modulation sensitivity, place a VTVM between terminal 2 or 7 of the 6AL5 socket and ground, using the lowest practical DC scale. The standard test signal for the audio section of the transmitter is 1000 cps, and this signal should be applied to the transmitter input. As the input is increased and approaches 0.25 volt, a slight wiggle will be observed on the meter, indicating that the peaks of the signal are being clipped. If the input is further increased, the meter reading will decrease.

The point at which the meter shows the slight wiggle is the clip level. While this is 0.25 volt for most transmitters, the service manual should always be consulted for verification; some transmitters use different values for their modulation sensitivity.

Microphones sometimes have outputs of 0.18 volt. When this is the case, the input coupling capacitor is connected to the alternate tap, allowing the full voltage to reach the audio amplifier input.

Measuring Deviation

In order to determine the amount of deviation, it is necessary to use a suitable deviation meter. With a 1000-cps sinewave signal at the input, the deviation should be set to a full 15 kc (or to 5 kc, when that value applies). When the input is not a true sinewave (voice modulation, for example), the deviation is adjusted for an indication of about 12 kc, using a sustained voice tone such as Ah-h-h-h-h--. Then, when we speak into the mike, the peaks should reach 10 kc on the deviation meter.

The scope, when used in conjunction with a deviation meter, becomes a most accurate indicator of deviation. It must first be calibrated, however. This can readily be accomplished with a deviation meter, using a signal which is below the clip level. The 1000-cps signal is applied to the audio section so that the deviation is 10 kc on the meter. The scope vertical gain is then adjusted for a convenient deflection, such as 10 squares, on the scope screening. (The scope controls must now remain in the same setting for the rest of the check.)

Since the deviation is increased by increasing the input voltage, the IDC circuit will eventually start clipping the amplitude, but the indications of the deviation meter and the scope may not agree. While the scope will show the true peak deviations, the deviation meter responds to the average deviation; its scale is marked according to the corresponding peak value rather than the average. This meter reading is accurate only so long as the input signal is a sinewave, and not clipped. As soon as the signal deviates from the sinewave, however, the peak will no longer have the same relative value with respect to the average value, and the deviation reading may not represent the true peak.

This does not mean that the deviation meter is not satisfactory for setting the deviation of the transmitter. The difference or error is very low for deviation values through 15 kc, and the error becomes significant only when the IDC circuit goes into full limiting.

The Motorola Monitor Measures Both Frequency and Deviation.

The foregoing discussion was based on an input signal of 1000 cps. Where the signal frequency is lower and clipping occurs, the average energy will be less in comparison to the peak than for the 1000-cps input. Thus, where a low-frequency signal is used, the deviation indicated by the meter for a clipped condition is likely to be lower than that recorded on the scope.

From the preceding discussions, we see that there are several factors that must be taken into consideration when trouble shooting the audio section of the transmitter. First and foremost is modulation sensitivity. If the modulation sensitivity is low, it should be corrected in the amplifier section rather than by advancing the IDC control. If the IDC control is advanced, there may not be an immediate change in the operation of the transmitter. If the control is advanced, however, because the amplifier gain is low, and then later the amplifier gain is restored to normal by replacing a weak tube, the IDC control must again be adjusted for correct deviation.

Another example of improper service procedure has to do with a weak mike. The serviceman finds that the modulation of the transmitter is weak and, rather than doing a little trouble shooting and finding out the reason, he merely advances the IDC control. This means that the audio input may never reach the clip level, and there may be no IDC action. Moreover, the weak mike eventually becomes inoperative and it must be replaced. The serviceman will be guilty of an error of omission if he fails to recheck the deviation. The output is good and loud, he reasons, so why worry about the amount of deviation! The deviation is now beyond the bandwidth of the receivers in the system and the Permakay filter in the receiver prevents some of the sideband energy from getting through to the discriminator. This results in a distorted output and a consequent sacrifice in quality. The excessive deviation also produces a lot of sideband energy which falls in the adjacent channels and interferes with systems operating within these channels.

If the modulation sensitivity is not up to par, either the amplification of the audio stage is low or the clipper is not working properly. A further check of these stages should disclose the specific trouble.[2]

Transmitter Alignment

The alignment procedure of any transmitter must include three steps: (1) the RF circuits must be adjusted so that the correct amount of power is delivered to the antenna, (2) the transmitter must be placed on the proper frequency, and (3) the modulation (deviation) must be correct.

To obtain the proper RF signal at the antenna, all of the circuits between the oscillator and

2. See Test Methods, section 2, pages 53, 54 and 57, also section 3, pages 34-36; also see "Let's Measure Modulation," reference M-6.

antenna must be tuned to their correct frequency and the coupling must be properly adjusted between the PA stage and the antenna. The circuits from oscillator to PA are tuned for maximum indications at the grids of the following stages. The PA plate tank is adjusted for minimum plate current. After the plate tank is tuned, the antenna coupling circuits are adjusted to obtain the proper amount of RF in the antenna (determined by the amount of plate current).

The service manual lists certain normal readings for each stage of the transmitter. Unless these readings are obtained, it is not advisable to proceed with the rest of the alignment, for the proper operation of each stage depends upon the grid drive from the preceding stage.

The actual power output of the transmitter cannot be accurately determined merely by knowing the amount of plate current in the PA stage. Power output is best measured by means of an accurate wattmeter connected between the transmitter and antenna. Instead of the antenna, a dummy load of the proper impedance may be used with the wattmeter. This wattmeter should read both forward and reverse power, particularly if it is terminated into the regular antenna system. A transmitter may fail to load properly because of a defective antenna system, and this is readily detected by means of the forward-reverse power readings on the wattmeter.[3]

This Portable Motorola Meter Accurately Measures the Frequency and Deviation of Transmitters, between 20 and 100 MC.

The frequency of the transmitter is determined basically at the oscillator. An adjustment at the oscillator stage provides for placing the transmitter at the correct frequency. By monitoring the transmitter output with a frequency meter the oscillator can be warped until the transmitter frequency is correct. The reliability of this procedure is limited only by the accuracy of the frequency-measuring device.[4]

Deviation measurement requires the use of a special meter to monitor the transmitter output during modulation.

Besides the general alignment procedure discussed in this lesson, specific recommendations for the individual transmitter must be followed in detail, particularly in the loading procedure for the

3. See Test Methods, section 3, pages 17-25.
4. See Test Methods, section 2, pages 32-39 and section 3, pages 10-15.

final stage. Unless the loading is correct, the final tubes may overheat and fail prematurely. Recommended procedures must be followed, also, in order to provide the specified amount of RF power output from the transmitter, with minimum harmonic radiation.

Parasitics

Parasitics, when encountered in transmitters, are usually recognized by the radiation of abnormal signals, signals which are not normal for the transmitter. The reading at position 6 (the final grid) is likely to be abnormally high and the tuning of the circuits erratic. The power output is usually low when measured on a wattmeter, and erratic when the final is loaded by the antenna or by a dummy load.

Further evidence of the existence of parasitics is the overheating of components, particularly the parasitic suppressors! Severe parasitic oscillations may even cause the suppressors to burn up.

One method of determining the presence of parasitic oscillations is to remove the drive from the final stage momentarily, while observing the behavior of the final grid and plate circuits. If the oscillations are strong, the wattmeter may indicate some powei output.

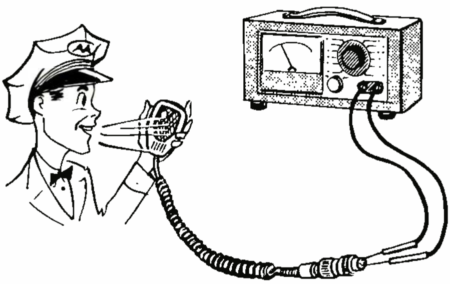
The most common causes of parasitic oscillations are defective bypass capacitors, and stages improperly neutralized. (It is essential that the neutralization procedure recommended by the manufacturer be followed in every detail.) Another likely source of parasitics is the final amplifier tube itself.

450-MC Transmitters

Before discussing troubles which may be associated with 450-mc transmitters, it is necessary to say something about circuit variations which may alter the trouble shooting and alignment procedures. This is the case where a metering circuit has been provided for measuring the power output. The meter does not give a quantitative indication of the power, but it does show peaks. It provides a means of tuning the final stage and loading the transmitter into the antenna the same as if a wattmeter were used.

Some 450-mc transmitters have a modulation sensitivity of 0.1 volt, which means that only this amount of voltage is required at the input terminals in order to cause the necessary deviation.

Another unique feature (in some 450-mc Motorola transmitters) is the use of variable coupling between the driver and final stages. Normally this coupling is fixed in



Establishing the Amount of Mike Voltage--As Measured on a Sensitive AC Voltmeter--is Helpful in Diagnosing Modulation Problems.

the transmitter, but it is desirable for it to be variable in certain instances, to obtain optimum operation of the final stages.

One of the most common complaints in connection with 450-mc transmitters concerns low power output. This is sometimes caused by the 2C39 tubes used for the final stages of some high-frequency transmitters.

When the power output is low, the first thing to check is the drive to the final and to the preceding stages. There is little reserve drive in the final stages; unless the driving voltages are up to par, the final cannot develop full power output. The final stage in Motorola transmitters is driven by a tripler stage, and the drive to this tripler is very critical. It is just as important to avoid overcoupling in this stage as it is to secure sufficient coupling. The coupling to the tripler grid is thus made variable and it must be properly adjusted by the serviceman.

The tripler coupling to the final stage can usually be set at maximum, provided no limit is specified in the alignment procedure. (This will vary from one model to another.) With the input to the final stage known to be satisfactory, the tuning and antenna loading procedures are checked. Then, if it is still impossible to obtain normal power output, a new tube should be tried in the final. The tripler-driver and the final use the same type tube in Motorola 450-mc transmitters, and these tubes can be interchanged for the purpose of comparing the power output. It is common for the final tube to operate satisfactorily in the driver stage even though it may not give full power output in the final stage.

Low power output may also be caused by low supply voltage, either filament or plate, and this possibility must never be overlooked. Another possible source of trouble is the contacts of tube filaments. Filament power is applied through these spring connectors, so they must make good contact. Poor contact causes loss of power and overheating. Low power output may be traced to defective bypass capacitors in the grid and plate circuits. These capacitors often make use of mica sheets which are held to the chassis by screws. If these screws should become loose, the capacitance is reduced and the power output decreases. The remedy is to simply tighten the screws. The ground return of the various coupling loops may be making poor contact with the chassis because of the accumulation of dirt. This also is a possible cause of low power. The remedy is to clean the ground contact.

250-Watt Transmitters

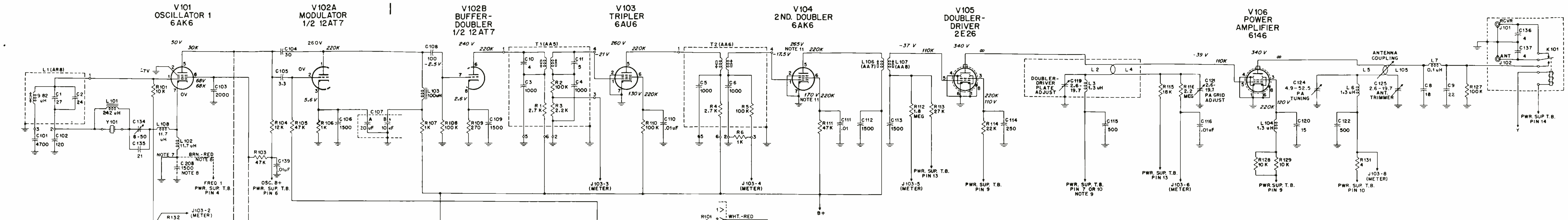
Quarter-kilowatt transmitters use an ordinary 30-60 watt transmitter as the driving section for the high-powered final. In most instances, the problems encountered are due to misaligned final stages.

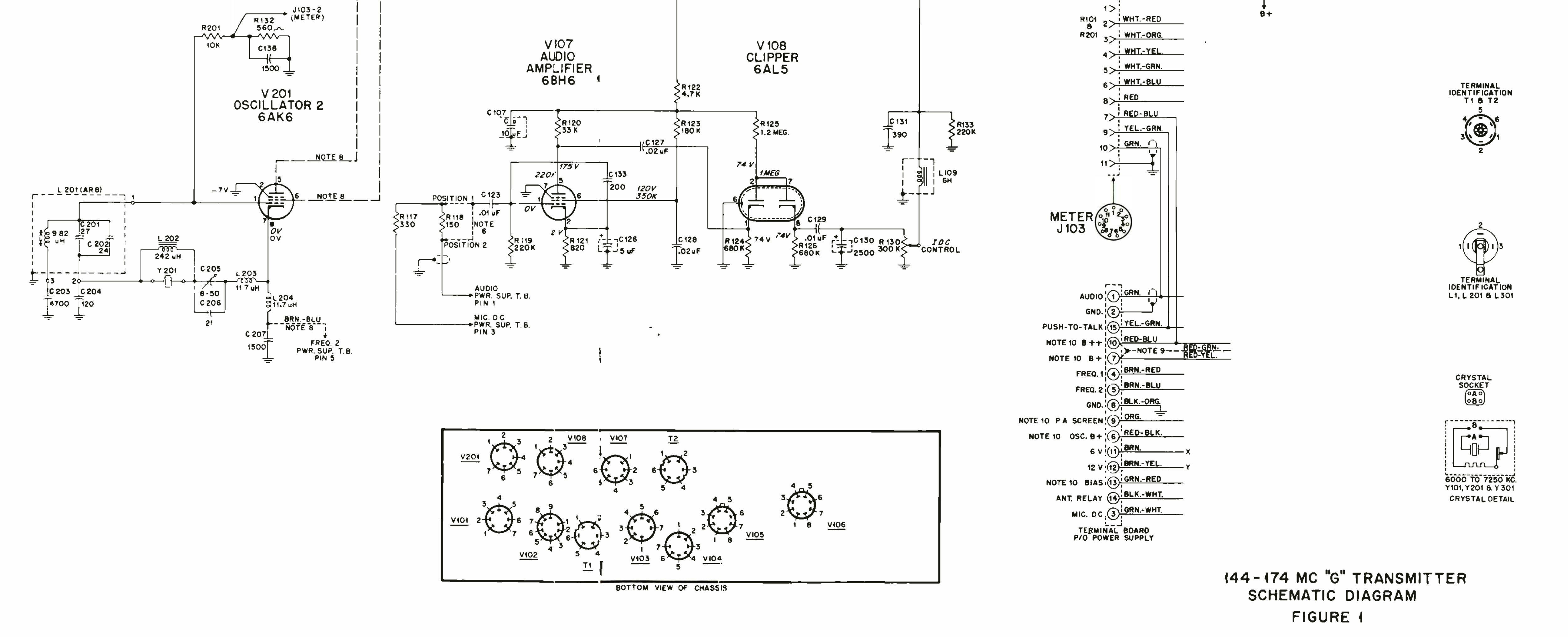
Neutralization is one of the most important factors in the tuning of 250-watt finals. This is required with both low-band and high-band units but not with the 450-mc transmitter, which is fixed-neutralized. No particular alignment, adjustment, or neutralization procedure is applicable for all models of 250-watt transmitters; the step-by-step instructions provided by the manufacturer must be consulted for each model.

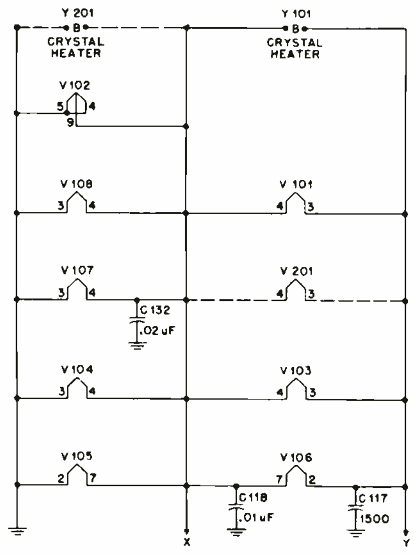
The antenna change-over relay may sometimes become a source of trouble, especially when its contacts become pitted or charred because of the higher RF power handled.

In working with transmitters, particularly high-powered units, the serviceman must exercise unusual care to avoid coming into contact with "hot" circuits. The high-voltage warning must be observed at all times. It is well for the serviceman to be thoroughly familiar with normal safety measures and first aid procedures.

STUDENT NOTES







NOTES:

1. UNLESS OTHERWISE STATED:
   RESISTOR VALUES ARE IN OHMS, ±10%, 1/2 WATT. K=1000 OHMS.
   CAPACITOR VALUES ARE IN MICROMICROFARADS.
2. LEGEND: IRON CORE ADJUSTMENTS:
   TOP TUNING   BOTTOM TUNING   TOP OR BOTTOM TUNING
3. ALL MEASUREMENTS TAKEN WITH A VACUUM TUBE VOLTMETER WITH RESPECT TO GROUND.
4. ALL VOLTAGE MEASUREMENTS TAKEN WITH A 1MEG RESISTOR IN SERIES WITH THE METER LEAD.
5. READINGS FOR V101, V201 AND V301 TAKEN WITH FREQUENCY SWITCH IN APPLICABLE POSITION.
6. CAPACITOR C123 IS CONNECTED TO POSITION 1 FOR PALM TYPE MICROPHONE OR TO POSITION 2 FOR HANDSET INPUT. REFER TO "AUDIO SENSITIVITY CONNECTIONS" IN THE TRANSMITTER INSTRUCTIONS FOR SPECIFIC DETAILS.
7. GROUND CONNECTION IN V101 CATHODE CIRCUIT USED ON SINGLE FREQUENCY MODELS ONLY.
8. DASHED CIRCUITRY AND 200 SERIES COMPONENTS ARE INCORPORATED ON TWO FREQUENCY MODELS ONLY.
9. DOUBLER-DRIVER PLATE LEAD(RED-GRN.) IS CONNECTED TO:
   PIN 7 OF ASSOCIATED POWER SUPPLY FOR 25 WATT APPLICATIONS;
   PIN 10 OF ASSOCIATED POWER SUPPLY FOR 10 WATT APPLICATIONS.
10. B+ VOLTAGE: 285 V, 10 WATTS RF POWER.
    270 V, 25 WATTS RF POWER.
    PA SCREEN VOLTAGE: 145 V, 10 WATTS RF POWER.
    270 V, 25 WATTS RF POWER.
    B++ (HI B+) VOLTAGE: 315 V, 10 WATTS RF POWER.
    335 V, 25 WATTS RF POWER.
    BIAS VOLTAGE: -17 V, 10 WATTS RF POWER.
    -20 V, 25 WATTS RF POWER.
    OSC. B+ VOLTAGE: 150 V, 10 WATTS RF POWER.
    150 V, 25 WATTS RF POWER.

TA139A Series Transmitters (10 Watts)

SWITCH POSITION	1	2	3	4	5	6	7	8	PA (+4)
METER SCALE READING	-	10	13	8	16	11	17	*	25

144-174 MC "G" TRANSMITTER SCHEMATIC DIAGRAM
FIGURE 1

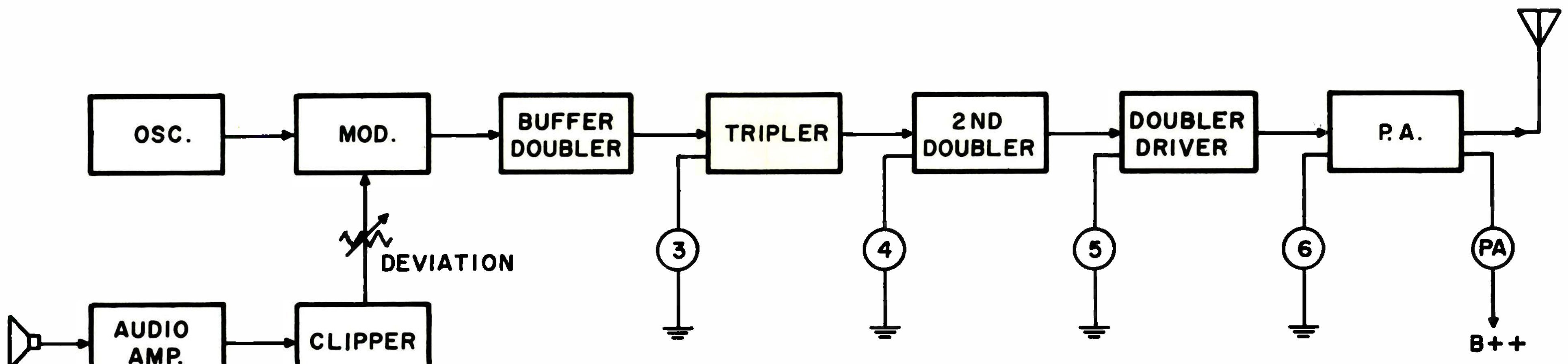

OSC.
MOD.
BUFFER DOUBLER
TRIPLER
2ND DOUBLER
DOUBLER DRIVER
P.A.
DEVIATION
AUDIO AMP.
CLIPPER
3
4
5
6
PA
B++

FIGURE 2

national
MOTOROLA
RADIO COMMUNICATIONS
service

A TWO-WAY RADIO COMMUNICATIONS TRAINING PROGRAM

LESSON MA-5
MAINTENANCE

Receiver Servicing

MOTOROLA TRAINING INSTITUTE

A TWO-WAY RADIO COMMUNICATIONS TRAINING PROGRAM

LESSON MA-5
MAINTENANCE

Receiver Servicing

—one of a series of lessons on two-way FM communications—

MOTOROLA TRAINING INSTITUTE
4501 W. AUGUSTA BLVD., CHICAGO 51, ILLINOIS
APPROVED BY THE STATE OF ILLINOIS
DEPT. OF REGISTRATION AND EDUCATION

PREFACE

This is one lesson of a complete Motorola Home-Study Course which presents to the Service Technician both the principles of operation and the maintenance of two-way FM radio systems. The program covers mobile, portable and base station equipment, including the latest transistorized units.

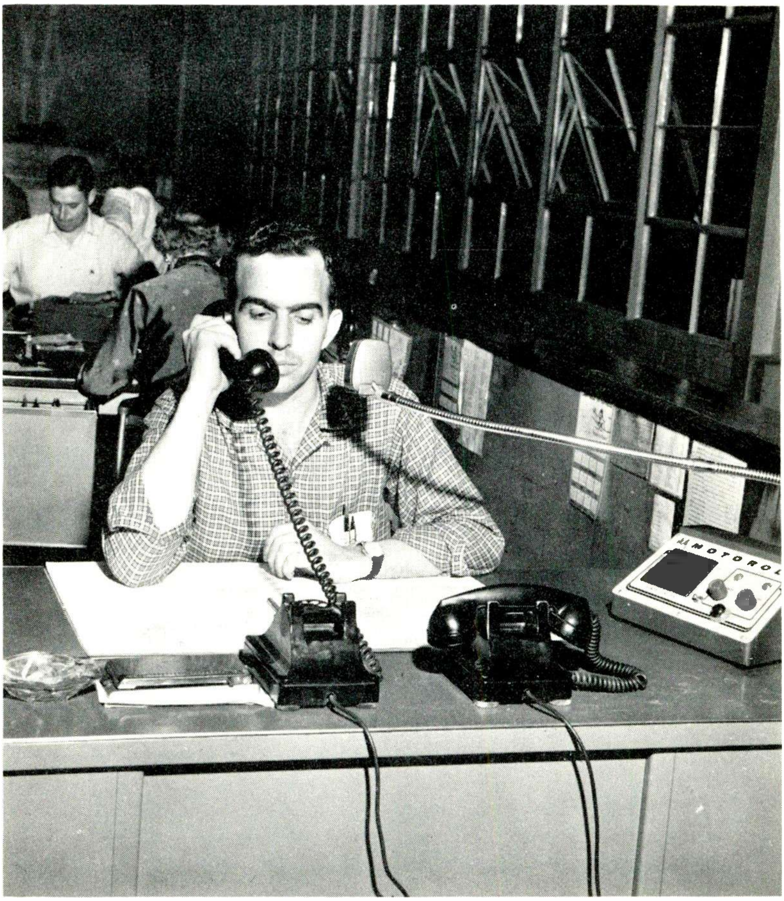
RECEIVER SERVICING

Lesson MA-5

TABLE OF CONTENTS

NOTICE

Diagrams and figures referenced in text are "fold-outs" in back of each lesson, for use while studying. The Examinations are also there.



Trucking dispatchers take only seconds to translate telephone pickup orders to radio dispatch calls. Many trucking companies are radio equipping all their pickup and delivery vehicles.

RECEIVER SERVICING

Lesson MA-5

Introduction

In this lesson we shall discuss procedures for quickly locating and correcting troubles within the two-way communications receiver. We shall concern ourselves primarily with the location and correction of a single fault, since a receiver rarely has more than one major trouble. If more than one fault does occur, we must find and correct them one at a time.

Before starting our discussion about receiver trouble shooting, we must assume that previous tests have been made which definitely establish the receiver as the offending unit. That is, we must assume that the power supply and the antenna system are normal.

The specific procedure for trouble shooting the receiver will vary considerably for each service problem; we may use one technique for the receiver in the vehicle and another for the receiver at the base station. The mobile receiver is the more common of the two, so we shall start our discussion with this unit.

The Mobile Receiver

The Trouble-Isolation Chart in figure 1 will serve as a useful step-by-step guide in trouble shooting the receiver. It lists a number of possible troubles and suggests corrective procedures. In this chart we assume the only test instrument available is a Motorola test set. (We are also assuming that there is no carrier frequency signal available for testing the receiver.) This chart is intended to apply specifically to the high-band receiver of figure 2, but the general procedure will apply to many Motorola receivers, of all bands.

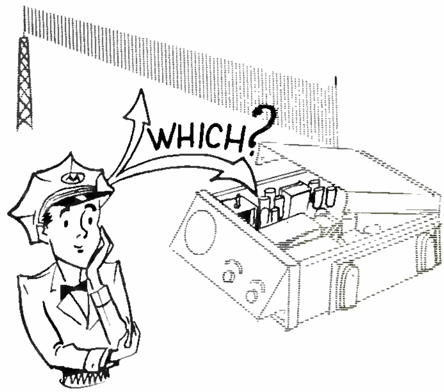
Audio Test

The first step when isolating trouble in a receiver is to turn the volume control full on and open the squelch wide (control fully counter-clockwise). A loud noise should be heard in the speaker. If there is no sound, the fault is likely to be in the audio or squelch sections of the receiver. We continue with procedure 2, to the left.

Here we use the Motorola test set (either the P-8501 A/B or the TU-546). With the test set plugged into the receiver and adjusted to measure the receiver output (position 8 of P-8501 tester; position 11 of TU-546 tester), we make two checks. First, if the speaker circuit of the receiver is defective, we shall hear noise in the test speaker. Second, the test meter measures the receiver output voltage. Let's first assume that the test set shows a reading and that a loud sound is heard in the test set speaker. We may immediately assume that the speaker or its circuit in the receiver is defective. If the receiver is mounted in the trunk, the speaker is a separate unit which interconnects to the receiver through the control head. It is likely that the wiring is defective. In some models the speaker wires plug into the control head, and one of these connections may be bad. If the trouble cannot be found through visual inspection, it may be necessary to use an ohmmeter or a substitute speaker.

If there is neither noise from the speaker nor a reading on the test meter, the speaker circuit is probably O.K. We now proceed to 3. Remove the noise rectifier tube in the squelch section and listen for sound from the speaker. Removing the noise rectifier disables the squelch section of the receiver and helps to further pinpoint the problem to either the audio circuit or the squelch circuit. If the squelch circuit is defective (if the coupling capacitor between the noise amplifier and the noise rectifier is leaky), there will be a constant positive voltage present at the DC control tube grid and the squelch will remain closed. If the squelch is to open, the negative voltage from the second limiter grid must be available and the positive voltage from the "noise section" must be removed.

If there is still sound after the noise rectifier tube is removed, try new tubes in the squelch section, procedure 4. If there is no change in the operation, the fault is in the squelch circuits and the receiver must be brought to the service bench for more detailed checks.



Failure to Hear a Message May Not be the Fault of the Receiver-- Check Carefully.

If there is no sound, however, with the noise rectifier tube removed, proceed to 5 and replace, one at a time, the audio, discriminator and second limiter tubes.

If replacing any of these tubes corrects the trouble, a high noise level will be heard and the receiver may be checked for normal operation. If, however, these tube replacements do not produce any change, the receiver must be further tested on the service bench.

RF and IF Tests

When the serviceman hears noise in the speaker after trying procedure 1, he immediately proceeds to 6 on figure 1. Here he takes readings in positions 1,2,4, 5 and 6 on the test set.

If the reading at position 2 is low (position 1 is normally low without a signal applied), the trouble is probably either in the front end or in the IF section. This includes both oscillators and mixers. It is not possible to isolate the trouble further within this large section of the receiver by making additional tests with the test set, so the best solution is to follow procedure 7. Replace the tubes, one by one, noting the change in the noise and in the meter readings, position 2 in particular.

It is sometimes possible, by noting the changes in noise level, to isolate the trouble within the entire front end of the receiver. If, upon removing the high-frequency oscillator or mixer tube, the noise does not decrease, the trouble is likely to be either in that stage or in a following stage. If the noise changes, the receiver is operating to some extent from this point on to the speaker, but some stages may be weak.

If tube substitution restores the meter reading at position 2 to near normal (and the other positions, as well), we may be reasonably sure that the trouble has been found and corrected. It is necessary, however, to completely check the receiver operation. This necessitates a brush-up on the alignment, particularly the netting of the receiver with the base station transmitter. If tube substitutions cause no change in the meter readings, we must look elsewhere before removing the set for bench servicing. First, the fault may be in the high-frequency oscillator, particularly in the matter of correct frequency. Second, the receiver may need realigning. If neither of these areas proves to be at fault, it may be necessary to further test the receiver on the service bench.

If the readings taken at metering positions 1 and 2 are normal, we next check the reading at position 6. Although this reading indicates oscillator activity, the test set doesn't actually measure the injection voltage from the oscillator plate circuit to the mixer. Besides, even if the reading at position 6 is normal, we cannot be sure that the injection signal to the mixer is at the correct frequency--the oscillator may be off frequency and require alignment.

If the reading at position 6 is too low, the next procedure, 8, is to try a new oscillator tube. If the new tube does not serve to restore operation, a crystal known to be good should be tried. If the readings are still too low, it will probably be necessary to remove the receiver from the vehicle for additional service. If the reading at position 6 returns to normal, the fault is corrected. It will still be necessary, however, to net the receiver frequency with the base station transmitter before placing it in operation.

When analyzing the readings at metering positions 4 and 5 (the primary and secondary of the discriminator), we have to take into account the readings at positions 1 and 2. If the reading at position 5 is low, we must first make sure that the readings at positions 1 and 2 are near normal. (If they are not, the fault is in the stages preceding the limiters rather than in the limiter or discriminator circuits. Thus, we are concerned with low readings at position 5 only when positions 1 and 2 are near normal.) If position 5 is still low, we should try new tubes in the limiter and discriminator stages (procedure 9 in the chart). Finally, if the reading remains low, either the receiver requires alignment or there is some other trouble for which it may be necessary to remove the receiver for bench service. If the readings are restored to normal when the new tubes are tried, it is well to check the alignment and noise idling before placing the receiver back in operation.

The reading at position 4 should normally be close to zero. When only noise is present, the idling of position 4 should be within two scale divisions of zero on the test meter. If the reading at position

Quick, Efficient Receiver Service Requires a Complete and Logical Trouble Shooting Plan.

4 is not at zero (with no channel signal applied), it is possible that the low or high frequency IF section requires retuning. Also, a strong carrier on some nearby channel may produce "noise," causing the discriminator noise idle to swing off zero. Further checks on the receiver alignment and system netting are required.

When the reading at positions 1, 2, 4 and 5 are normal, the trouble may be due either to (1) off-channel operation of the receiver, or (2) low sensitivity in the receiver front end. For off-channel operation we may follow the suggestions under the "reading at position 6" block; for low sensitivity, follow the suggestions of procedure 7.

Using a Signal for Isolation of Trouble

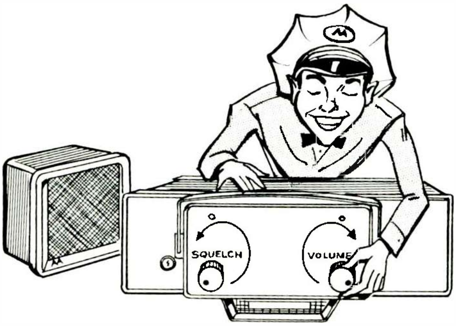
When a signal on channel frequency (such as one of the transmitters of the system) is available, it is often possible to determine the trouble more quickly and with greater reliability. The Motorola test set may also be used as a source of signal.

In general, we should start our trouble shooting in the same manner as recommended in the chart of figure 1. Unless there is some noise in the speaker (a "live" sound), there is no need for the channel signal; we already know that the trouble is likely to be in the audio or squelch circuit. Also, the reading at position 6 should be normal, for without the high-frequency oscillator working properly there would be no heterodying action and thus no IF to measure or to cause noise quieting.

Assuming then, that we have established the presence of noise in the speaker and that we have obtained a normal reading at test set position 6, we may now check any change in the readings at positions 1,2,4 and 5, with the signal applied. It is also important to note any change of noise heard in the speaker when the signal is applied.

Unless the readings in positions 1 and 2 show a reasonable increase and the noise quieting approaches 20 db, the main trouble is in the front end or IF sections of the receiver. Figure 4 is another trouble-isolation chart similar to procedure 6 of figure 1, one that we can use when a channel signal is available.

Starting with the readings at positions 1 and 2, we find three possible variations: (1) the readings do not change, (2) they change but very little, (3) they change appreciably. If the readings change very little (or not at all), and if there is little if any noise reduction, we should recheck position 6. If this is O.K., we then follow procedure 7 in figure 1. When the readings at positions 1 and 2 increase appreciably with a signal applied and some noise quieting is noted, we know that both sections of the oscillator-mixer are working normally. However, there are still two possible trouble sources. The sensitivity may be low, or the high-frequency oscillator may not be at the correct frequency.



A Quick Check On Receiver Operation is Made by Turning the Volume Full-On and Opening the Squelch.

For the low sensitivity condition, follow procedure 7 in figure 1. If this proves good, check the test set reading at position 4. Position 4 may show no change, read zero on signal, or swing away from zero. If there is no change in the reading and noise quieting, the trouble is in the limiter or discriminator stages; try replacing tubes. If this does not correct the fault, the receiver probably requires further servicing with additional test equipment. If the reading swings away from zero when a signal is applied, the high-frequency oscillator is off frequency and may be warped back to zero. (Be sure that the discriminator reads zero with a 455-kc signal.) If the reading shows zero with the signal applied, the oscillator frequency is correct; the trouble, if any, is in either the front end or in the IF stages. See the suggestions of procedure 7 in figure 1.

The readings at positions 5 and 6 do not add appreciably to our present type of trouble shooting technique, for these readings are not likely to change to any extent with an applied signal. Only if the incoming noise fails to saturate the last limiter will there be any change at position 5. There is no normal trouble that might occur which could produce a change at position 6.

To summarize our discussion about the use of a signal to help isolate trouble in the receiver, we see by comparing the readings on the meter that:

1. If the readings at 1 and 2 do not increase and there is no noise reduction, the trouble is in the front end, ahead of the limiters.

2. If there is an increase in the readings at positions 1 and 2 and in the noise quieting, the reading at position 4 immediately tells us whether the receiver is on channel or not.

When to Remove Set for Bench Service

Up to now we have dealt with the receiver in the vehicle. We have implied, however, that on occasion further servicing required its removal to the service bench, that more comprehensive testing was required than could be done with only a test set. Whether we immediately remove the radio set or test it further in the vehicle depends upon the vehicle use. A police squad car, for example, can be out of service for a limited time only. If the trouble cannot be corrected within this time, the radio must be removed for servicing.

Where spare units are available for replacement, minimum time should be spent in servicing the equipment in the car. As soon as the serviceman is convinced that the fault is not a simple one, such as a defective tube, he should replace the unit with the spare and bring the defective set to the shop. This unit, when repaired, will then become the "spare" for the next car which requires it. This procedure saves considerable time for both the serviceman and the customer. By a spare we mean a complete installation, the receiver, transmitter, and power supply. These units are assembled together on a single frame and they are removed from the housing as a single unit. The original set can be removed and the spare installed in a matter of a few minutes. The spare is then checked out with the base station and the vehicle is ready for service.

In many instances the out time of the vehicle is not so important to the owner and it may be practical for the serviceman to make more checks on the receiver and attempt to service it without removal. This is particularly true where the serviceman has additional test equipment available.

In the remainder of this lesson we will discuss several bench service procedures and techniques. These same procedures may apply in general to the receiver while still installed in the car.

Alignment

While general alignment procedures can be given for typical receivers, we shall learn more by referring to a specific receiver chassis. We shall accordingly use the Motorola Sensicon "G" receiver, shown in figures 2, 3 and 5.

Figure 2 is the schematic diagram of this receiver, and figure 5 (which also includes the alignment chart) shows the parts placement as viewed from the top. Although this is designated as the complete "bench" alignment procedure, it can also apply to receiver alignment at the vehicle.

The following test equipment will be required to align the receiver: (1) a Motorola test set and a 455-kc crystal; (2) a Motorola model TU576 signal generator (or equivalent); (3) a known source of signal at the channel frequency. A frequency meter of acceptable accuracy can be used to set the signal generator to the channel frequency.

The photo in figure 5 shows the connections between receiver chassis and test set. The power supply for the receiver is not shown, since the receiver will usually be left in the complete assembly along with the transmitter and power supply.

The first step is to align the circuits tuned to the last IF frequency, 455 kc. This requires the test set and a 455-kc crystal. The adjusting procedure for the test set will be found at the left of figure 5. We first adjust the discriminator primary. A shorting wire is connected across the secondary terminals of the transformer assembly, and the meter switched to position 5. Then, with the generator supplying a 455-kc signal to the grid (pin 1 of V106, figure 2), the primary is adjusted for a maximum reading on the meter. Resonance is indicated by a relatively sharp peak. The primary is adjusted from the bottom of the chassis. After adjusting the primary slug to resonance, the locknut is tightened. Once this adjustment has been made, it is not likely that the primary will require a readjustment for some time.

The next step is to tune the discriminator secondary. Remove the short across the secondary, switch the meter to position -4 or 4, and adjust the secondary for a zero setting, which must be midway between positive and negative peaks. The secondary slug is adjusted from the top of the discriminator transformer assembly.

The remaining 455-kc adjustments are in the IF plate circuits; the tuning procedure appears in steps 3, 4 and 5 of figure 5. The signal is coupled to the input of the Permakay filter. The level is kept low, so that the readings are always linear with any increase in signal strength. Too strong a signal will cause saturation, in which case the readings will show little or no increase. The meter is set to position 2 and L16 is adjusted for a maximum reading. With the meter in position 1, IF coils L15 and L14 are tuned for maximum. This completes the alignment of the low IF section.

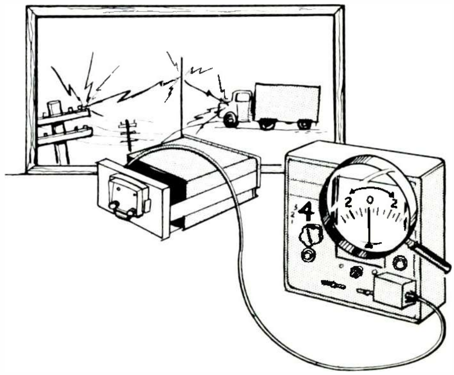
The 12-mc section is tuned next (steps 6 and 7). The 12-mc IF frequency is supplied by the signal generator, and its frequency is first adjusted for zero at the discriminator output (position 4). The 12-mc signal heterodynes with the second oscillator frequency at the second mixer, thus producing the 455-kc signal in the last IF section. If a satisfactory reading is obtained at positions 1 or 2, the signal generator is next coupled to the grid of the first mixer. If the reading is not satisfactory, however, it may be necessary to couple it to the grid of the first IF amplifier, V104. With the generator coupled to the grid of V104, coils L11, L12 and L13 are adjusted for maximum. With the generator at the first mixer grid, coils L8, L9 and L10 may be adjusted for maximum.

It is important to check the generator occasionally, making sure it remains at 12 mc throughout the adjustments. This is particularly true during the warm-up period, for the generator is likely to drift during this period. A quick check can be made by observing the reading at meter position 4; the reading must remain at zero. This completes the alignment of both the high and the low IF sections of the receiver. All that remains are the oscillator-multiplier and RF circuits.

With no signal applied and the meter at position 6, L5 is adjusted for maximum oscillator output. First, however, it is important to preset the trimmer capacitor C110 in the oscillator so that the tuning slot is parallel with the chassis. This places the oscillator close enough to its correct frequency so that the circuits will be adjusted for maximum even if a slight change of frequency becomes necessary.

After L5 is adjusted for maximum activity, the multiplier coils must be tuned. This requires a signal at the channel frequency, and the signal generator is used for this purpose. The signal generator is first set to the channel frequency in accordance with step 9 in figure 5. With the channel signal applied at the mixer or at the RF grid (antenna input), L6 or L7 are adjusted for a maximum reading at positions 1 or 2. (Unless the receiver sensitivity is maximum, it may be necessary to use position 2 for these initial adjustments.)

The RF coils are adjusted next. With the channel signal applied to the grid of the RF amplifier, L2, L3 and L4 are adjusted for a maximum reading at positions 1 or 2. If a reading can be obtained with the signal applied to the antenna input terminals, it is permissible to adjust the coils in this manner instead of injecting the signal directly at the grid.



A Properly Aligned Receiver will "Noise Balance" within Two Scale Divisions of Zero in Position 4 on the Test Set.

The antenna coil is now adjusted by applying the RF signal through a 6-db, 50-ohm pad to the antenna connector and adjusting L1 for a maximum reading at position 2. (If the reading is satisfactory, use position 1.)

The receiver is finally adjusted for the exact channel frequency. This is done by "netting" the receiver frequency to that of the transmitter with which the receiver normally operates. The transmitter must be turned on; then, with the meter in position 4, C110 is adjusted for a zero reading.

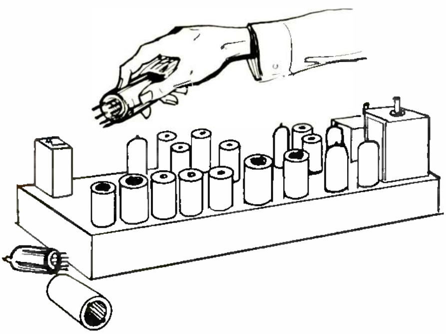
After the receiver has been netted to the base transmitter, it must be checked for "noise balance." Effective noise balance can be realized only after the receiver has been netted to the carrier it is to receive. As shown in step 13 (figure 5) of the alignment procedure, this also requires the receiver to be installed in the vehicle. The vehicle motor is left running while a signal at the channel frequency is received from the base transmitter. Ideally, this signal should cause a quieting of from 20 to 30 db. The plate coil of the first stage in the low IF section may now be retuned slightly for a reduction of ignition noise. In making this adjustment it is most important to observe the meter reading at position 2, which must not decrease more than one-half microampere (half-scale division on the meter). If the above procedure is unsatisfactory, the first IF plate coils can be used. The readings of the first IF are sharper, however, and this procedure may cause a detuning of the circuit, lowering the receiver's sensitivity. It is thus necessary to observe the meter reading at position 2 closely while making this adjustment. Noise balance is best achieved in different parts of the receiver depending upon the particular model and circuit. Always proceed according to the recommendations of the service manual.

Unless the noise adjustment is made for the exact carrier frequency which is to be received, it will not be effective when the receiver is put in actual operation. Furthermore, when the correct noise adjustment is realized, the idling of position 4 without a signal should fall within one or two microamperes of zero. This means that the discriminator balance for the noise input should be within 1 or 2 scale divisions (position 4) when the signal is removed. Failure to realize this noise idling indicates that the second IF section is not aligned to the center of the Permakay filter. When this occurs, it is best to recheck the alignment of the 455-kc circuits as well as the adjustment of the ignition balance.

Sensitivity Check

Whenever the receiver has been aligned or any general service has been performed, a sensitivity check should follow, in order to make sure that the receiver will work satisfactorily.

A sensitivity check requires a T1034A signal generator (or equivalent) and some kind of output indicating device such as a sensitive output meter. In position 8 the Motorola P8501 test set can be used as a convenient output indicator for the receiver. The quieting sensitivity of the receiver is the amount of RF signal required at the receiver input in order to reduce the receiver noise by 20 db. The squelch control is turned completely counterclockwise to open the squelch circuit, and the audio volume is adjusted for approximately 0. 5 volt output. If the P8501 test set is being used, the receiver volume is adjusted for a reading of 10 on the meter; if an AC output meter is used, the volume is adjusted to any convenient value, such as 0. 5 volt.



In Tube-Type Receivers, Most Troubles are Repaired by Replacing a Defective Tube.

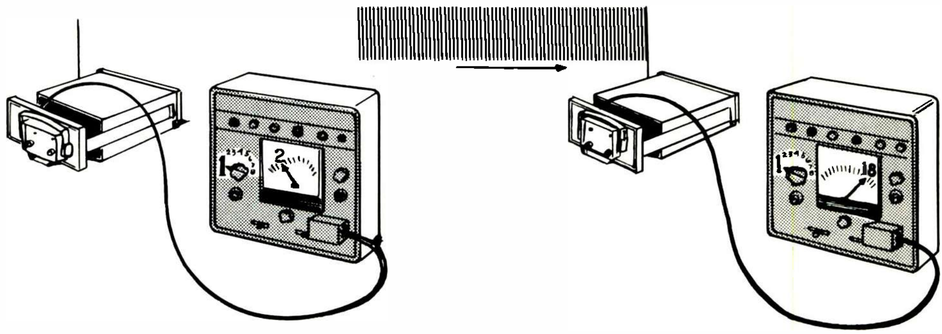
Connect the signal generator through a 6-db, 50-ohm pad to the antenna connector and place it on channel frequency by monitoring position 4 on the test set. The generator output is then returned to zero and increased until the output reading is reduced to one-tenth its original value. The generator output, in microvolts, is the receiver sensitivity. This value should be checked against the receiver specs. If the receiver is not up to full sensitivity it would be well to determine the reason and make the necessary corrections. Sensitivity may be improved by touching up the alignment in the front end of the receiver, or by substituting new tubes in the front end stages. The supply voltages, both A and B, should also be checked. After these areas have been exhausted as possible sources of poor sensitivity, check the meter readings on the test set. It may be necessary to make stage gain checks.

Stage Gain Measurements

Stage gain measurements are shown in figure 6. The instruments and terminations recommended are important if representative readings are to be secured, and they must be followed in detail. The stage gains shown in figure 6 can be realized only when the receiver is properly aligned. If there is any doubt on this score, the receiver should be completely aligned as recommended in the instruction manual.

By comparing the actual reading (with the meter in positions 1, 2, 4, 5 and 6, respectively) with the corresponding reading in the chart, an indication of the general operation of the various circuits can be obtained. By measuring the gain of the receiver at each stage, the one causing the low sensitivity is readily isolated. Voltages and resistance measurements can be made to determine the defective component within the stage.

The following example of trouble shooting by means of stage measurements is typical. Let's sup-



Comparing Meter Readings With and Without a Channel Signal is Very Helpful in Trouble Shooting the Receiver.

pose that the meter reads low in positions 1 and 2, when measuring noise input. The 12-mc input of 5 uv to pin 1 (grid) of V104 gives the correct 20-db quieting, but a 12-mc input of 3.0 uv at the mixer grid (pin 6 of V103) does not give 20 db of quieting, nor does a signal of 30.0 uv give a reading of -2 at position 1. This indicates that the gain between the grid of V103 and the grid of V104 is not correct, and the fault is probably in the grid or plate circuit of V103. Voltage checks are now made at the plate and cathode. If these readings are approximately correct, resistance tests may be made on the stage, including the plate coils. These may be tuned in the normal manner for checking the proper peaks. Failure of a coil to show a sharp peak indicates a definite fault in the tuned circuit. Open coupling capacitors must also be considered, although this condition results in sharp tuning with poor sensitivity. Because of their small capacitance, these units cannot be easily tested; it is usually better to substitute another capacitor and compare the results.

The effect of an open coupling capacitor depends on the amount of signal present as well as on the location of the capacitor. At the sensitivity level of the receiver, the relatively weak signal will find little coupling from one circuit to the next and the receiver may be completely dead. With a strong signal, however, it is very probable that the signal will be coupled from one circuit to the next even though the "coupling" capacitor may be open! Under these circumstances the receiver may operate fairly well, though its sensitivity will have been considerably reduced.

The results will also depend on whether the coupling capacitor is in the RF section or in the first IF section. Stray coupling is always more likely to occur at the higher frequencies.

When making stage gain measurements the correct procedure is to start at the last stage of the set and continue toward the antenna, until the point is located. The trouble is thus pinpointed to a particular stage in the receiver.

Discriminator Response Curve

One of the most important factors in securing clarity of the message reproduced by the speaker is for the discriminator "recovery slope" to be linear over the deviation limits of the system. This subject was discussed in the receiver lesson dealing with discriminator action. The discriminator response curve must be linear over a frequency range greater than the deviation employed by the system and in general this linearity is one and one-half to two times that of the deviation. This allows for some shift in the incoming IF signal and for possible detuning of the discriminator secondary.

The linearity of the audio recovery can be determined with the test set, using crystals 15 kc above and 15 kc below the center frequency of the last IF.

Each kilocycle of deviation in a 15-kc deviation system should produce approximately one volt at the discriminator output--at 15 kc from center frequency the discriminator output should be at least 15 volts. By comparing the output at 15 kc above center and 15 kc below center, the linearity of the discriminator will be known. A 10 per cent variation of the output voltages is permissible, but any greater difference represents too much distortion. When this occurs, recheck the alignment of the discriminator primary, the secondary, and the last IF section. If the receiver is operating on a 5-kc deviation, the output voltage should be at least 15 volts for the 5-kc deviation. These voltage checks are made at the full discriminator output, not at the input to the first audio stage. (In figure 2 this is at pin 5 of the 6AL5 discriminator tube base.)

Where the DC type of volume control is used, the output of the second limiter will be controlled to some extent by the setting of that control. For an accurate check, therefore, the volume control must be set temporarily at maximum.

Audio Stage Gain Measurements

While normal problems in the audio stage usually will not often require stage gain measurements, a system for determining relative audio levels should be known. In order to check the entire audio section, it is also important to test the deemphasis section. The audio input should thus be fed to the discriminator output, pin 5 of the 6AL5 tube socket.

For discussion purposes, typical readings were taken for the receiver circuit of figure 2. It should be kept in mind, however, that these figures are typical of one receiver only, and a 10 per cent variation from one receiver to another of the same model may be expected. Moreover, different receiver models have different gain requirements, and great variations may be found. The test signal was taken at 1000 cps. With frequencies other than 1000 cps, different gains should be expected.

The volume and audio level controls were first adjusted to maximum; the 1000-cps signal was then applied to pin 5 of the 6AL5 socket and adjusted to a level of 10 volts. The voltage at the grid of the first audio amplifier was 0.5 volt. This loss can be attributed to the deemphasis network and the large resistor R141 in series with the audio level control. The audio output at the plate of the first amplifier was nearly 9 volts, a stage gain of 18 (0.5 volt to 9 volts), or 25 db. There is some loss in the coupling from the first audio stage to the power amplifier, and the voltage at the grid of the 6AQ5 was 8.5 volts. The output voltage was measured at both the plate of the tube and at the lead to the voice coil (transformer secondary). These voltages were 110 volts and 2.5 volts, respectively. The output stage is designed to deliver a specific amount of power to operate the speaker, and the desired power for this receiver is two watts. The power output equals the voltage squared, divided by the resistance. The square of 2.5 is 6.25; dividing this by 3, the impedance of the voice coil, results in more than 2 watts.

By making such audio measurements on any receiver you may be servicing, you will know what the voltage levels should be when the equipment is operating in a normal manner. Then, when something happens, a second set of readings may be taken for the audio section and the results compared. These typical readings may be recorded for quick reference at any time. In fact all the readings of any receiver should be kept for future reference. This data is most valuable, for it immediately shows which circuits have changed since the last readings were taken.

When making stage gain measurements, it must be remembered that the signal level will have some effect on the amplification of the various stages, particularly in the audio section. The gain for a strong audio frequency signal may be considerably different from that of a weak audio frequency signal. More accurate results can be obtained by using a typical signal level such as the one illustrated above. Such a signal also indicates whether or not the audio power output is up to par. Too large a signal overdrives the tubes, causes distortion, and lowers the net gain.

Oscillation

In a two-way communications receiver, oscillation may take place without the operator or serviceman being aware of the fact. Oscillation within one of the stages or sections of a receiver is thus a problem which must be anticipated by the serviceman.

Oscillation may have various effects upon the receiver, depending upon the strength of the oscillation and where it is taking place. One of the most common effects is a partial quieting of the noise usually heard in the speaker when the receiver is unsquelched. The oscillation acts like a signal at the limiters, reducing the noise. Following this noise reduction, we can also expect that the noise level might be so low that the squelch circuit would be unable to squelch the receiver.

It is a characteristic of most oscillations that they produce higher than normal meter readings for the limiter grid circuits and the discriminator primary. Moreover, the discriminator secondary reading may be full scale in either direction rather than at zero, and alignment adjustments may be critical and erratic.

Trouble-shooting techniques such as "tube-pulling" and "grid-grounding" usually show which stage or section is oscillating. Oscillation usually occurs in the RF section of the receiver or in the last IF section, and pulling the front end tubes will usually pinpoint the oscillation to one of these two areas.

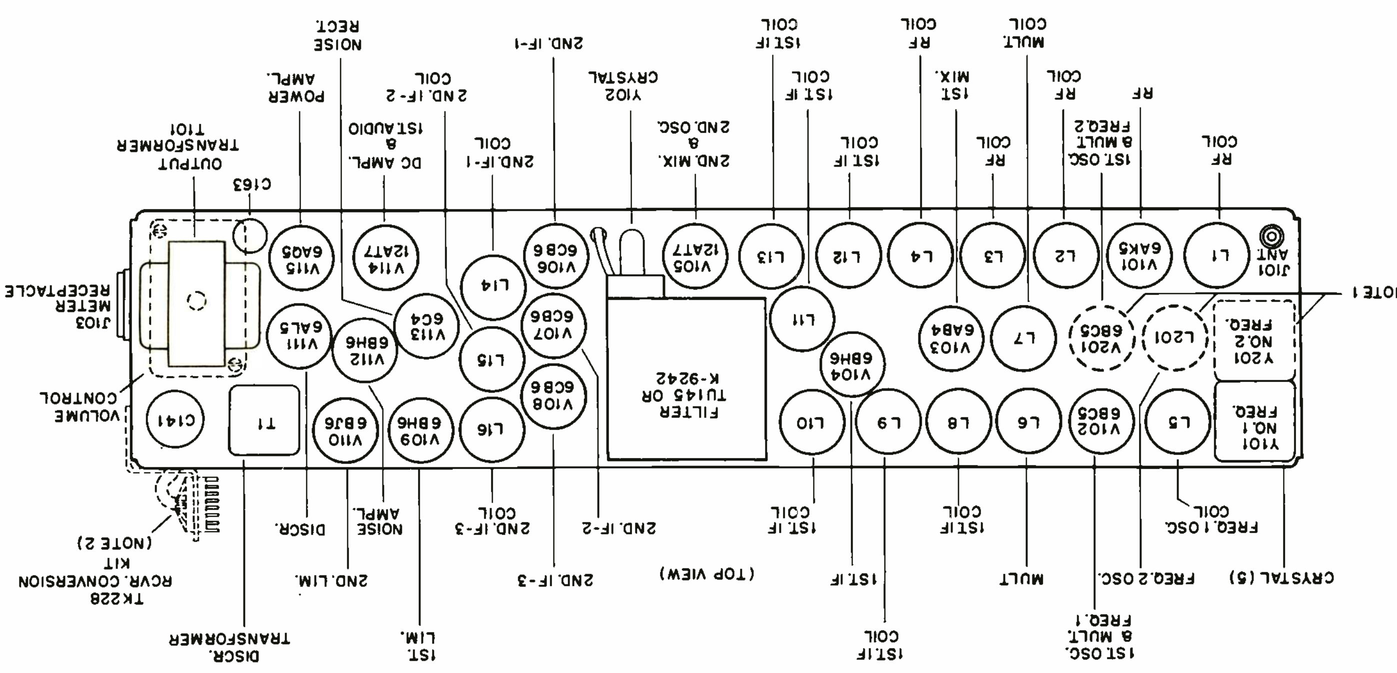
Common causes of oscillation are open bypass capacitors, broken ground leads, coupling capacitors out of position (away from the chassis instead of next to the chassis), ungrounded shields, and excessive supply voltages. The oscillating section of the receiver can often be found by bringing the hand close to the suspected section and noting the change in the meter readings, or in the sound coming from the speaker. When testing for oscillation, the input should always be terminated either into its antenna or into a 50-ohm load. Unless this is done, the RF stage is likely to oscillate.[1]

1. See Test Methods, section 2, pages 61-86, and section 3, pages 5-10.

STUDENT NOTES

144-174 SENSICON "G" RECEIVER
PARTS LOCATION DETAIL
FIGURE 3

NOTES:
1. Y201, L201 & V201 ARE USED ON 2 FREQUENCY MODELS ONLY.
2. TK228 RECEIVER CONVERSION KIT USED ON TA163-A SERIES MODELS ONLY.



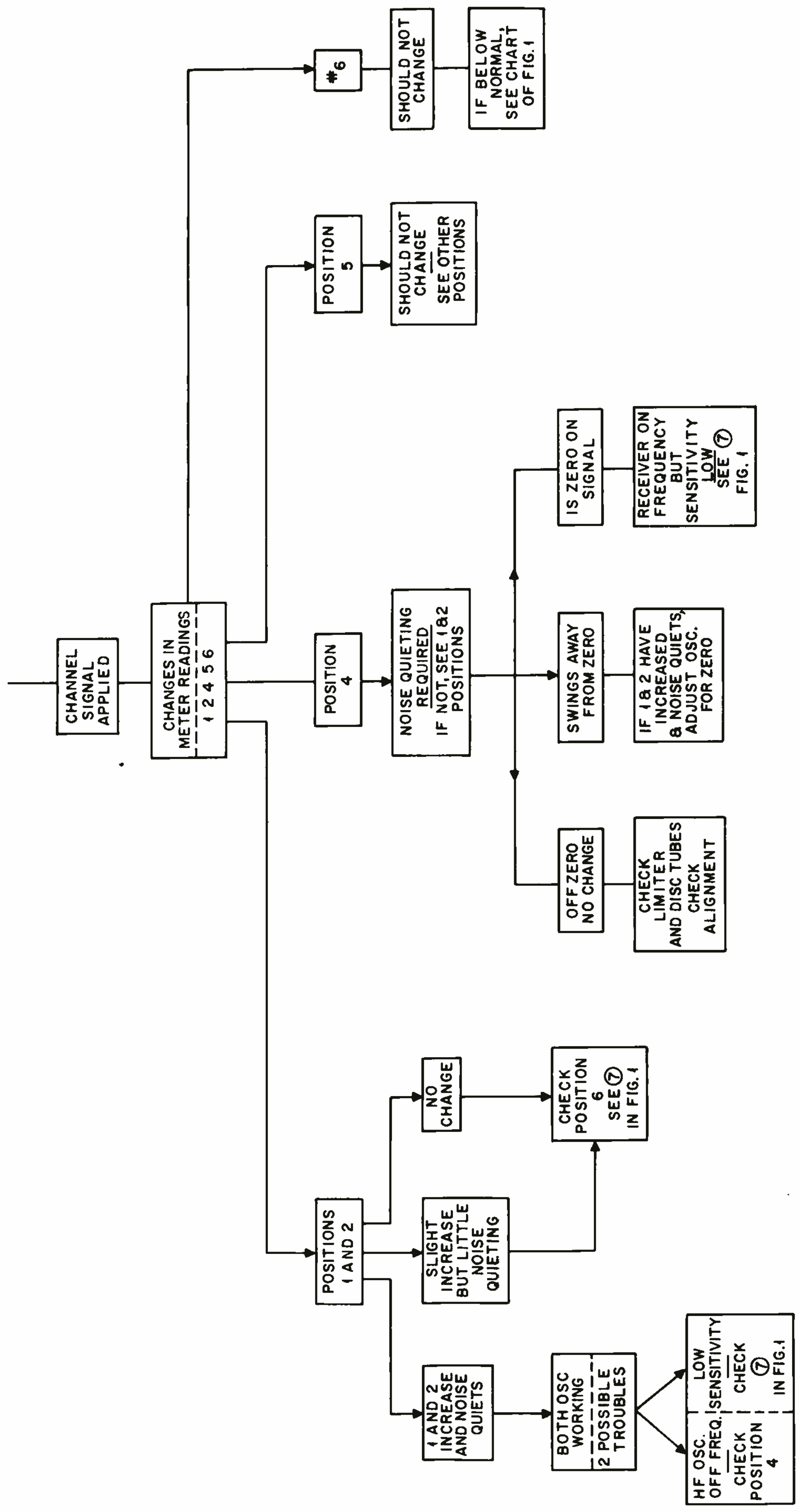


FIGURE 4

RECEIVER TROUBLE – ISOLATION CHART
NO SIGNAL AVAILABLE

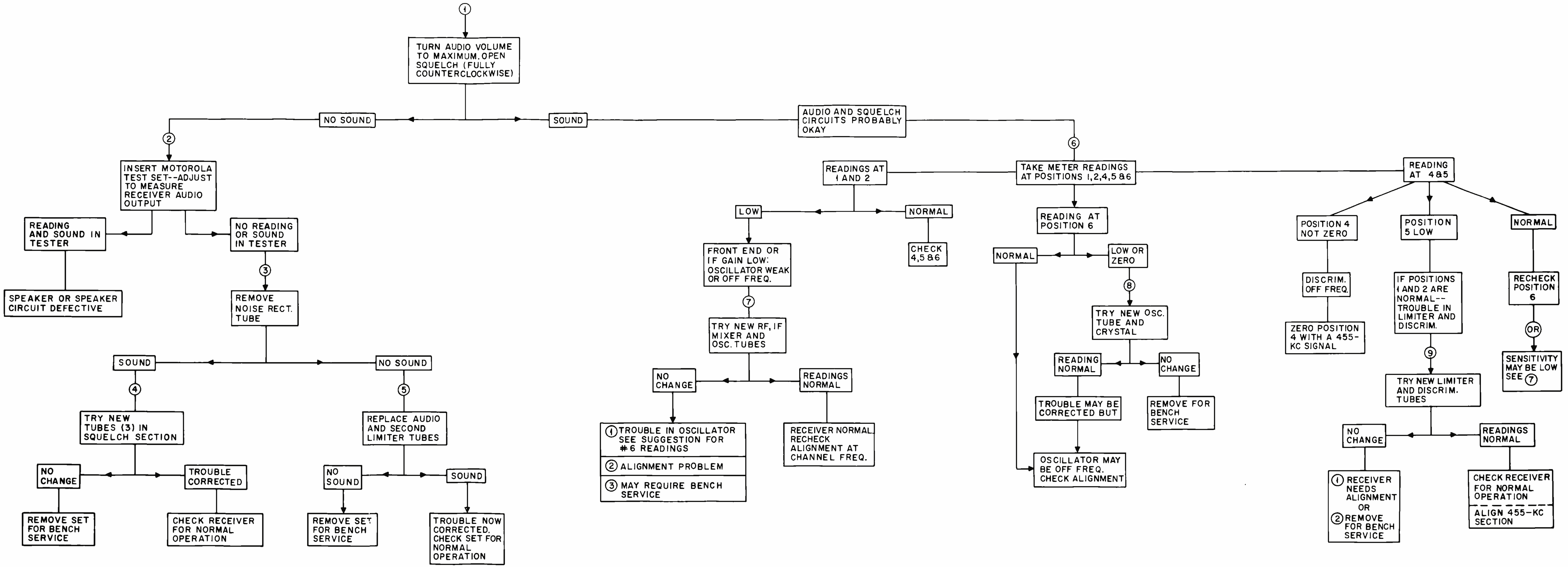
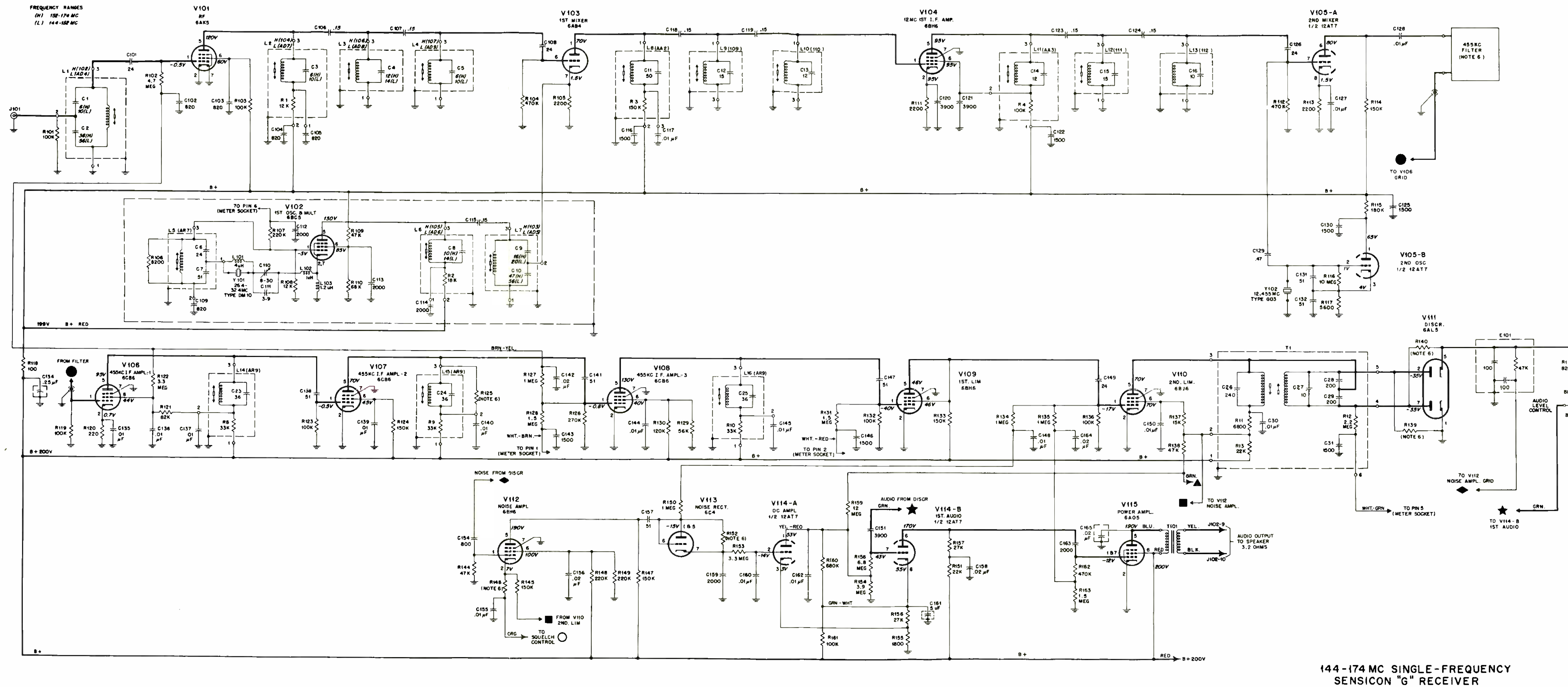


FIGURE 1



NOTES:

1 REFER TO PARTS LIST

2 ALL RESISTOR VALUES ARE INDICATED IN OHMS $\pm$10%, 1/2 WATT UNLESS OTHERWISE STATED. K = 1000 OHMS

3 ALL CAPACITOR VALUES ARE INDICATED IN MICROMICROFARADS UNLESS OTHERWISE STATED.

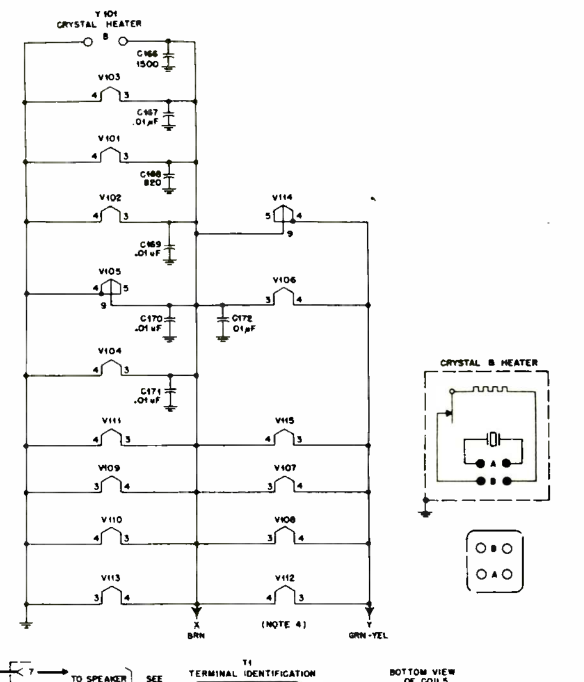
4 HEATER INPUT VOLTAGE FOR 'X' FILAMENTS IS ALWAYS 6VDC 'Y' INPUT VOLTAGE IS ZERO (GND) WHEN OPERATING FROM A 6VDC PRIMARY POWER SOURCE OR 12VDC WHEN OPERATING FROM A 12VDC PRIMARY POWER SOURCE.

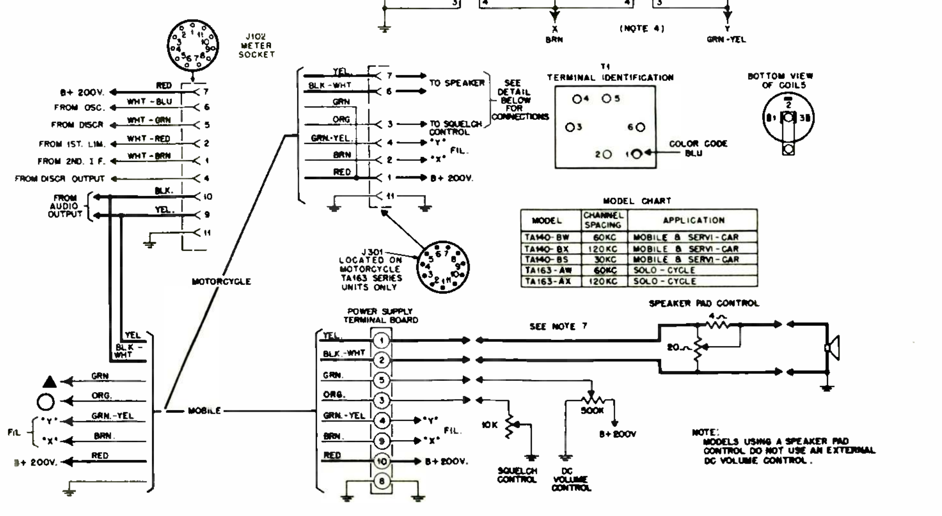
5 ALL VOLTAGES MEASURED WITH A VTVM (B+ = 200V) AND WITH THE SQUELCH CONTROL AT MINIMUM (COUNTERCLOCKWISE) AND DC VOLUME CONTROL AT MAXIMUM (CLOCKWISE).

6. COMPONENTS NOTED DIFFER IN VALUE FOR THE VARIOUS RECEIVER MODELS FOR WHICH THIS DIAGRAM IS APPLICABLE. REFER TO THE FOLLOWING TABLE FOR SPECIFIC IDENTIFICATION

COMPONENT	MODELS				
	TA140-BW	TA140-BX	TA140-BS	TA163-AW	TA163-AX
FILTER	TU-145	K-9242	K-9240	K-9241	K-9242
R125	18K	18K	100K	18K	18K
R146	680	680	220	680	680
R152	560K	560K	820K	560K	560K
R139	56K	56K	180K	56K	56K
R140	56K	56K	180K	56K	56K

7. TWO DIFFERENT METHODS OF VOLUME CONTROL ARE USED
A DC CONTROL
1 GREEN LEAD CONNECTED TO TERMINAL 5 ON POWER SUPPLY TERMINAL BOARD IS CONNECTED TO THE MOVING ARM OF THE DC VOLUME CONTROL
2. SPEAKER IS CONNECTED DIRECTLY TO TERMINALS 1 & 2 ON POWER SUPPLY TERMINAL BOARD.
B PAD CONTROL
1. GREEN LEAD CONNECTED TO TERMINAL 5 ON POWER SUPPLY TERMINAL BOARD IS CONNECTED DIRECTLY TO B+.
2. POTENTIOMETER AND 4 OHM RESISTOR IS INSERTED BETWEEN TERMINALS 1 & 2 ON POWER SUPPLY TERMINAL BOARD AND THE SPEAKER.





MODEL CHART

MODEL	CHANNEL SPACING	APPLICATION
TA140-BW	60KC	MOBILE & SERVI-CAR
TA140-BX	120KC	MOBILE & SERVI-CAR
TA140-BS	30KC	MOBILE & SERVI-CAR
TA163-AW	60KC	SOLO-CYCLE
TA163-AX	120KC	SOLO-CYCLE

144-174 MC SINGLE-FREQUENCY
SENSICON "G" RECEIVER
SCHEMATIC DIAGRAM
FIGURE 2

STUDENT NOTES

STAGE MEASUREMENTS

APPROX. MICROVOLT INPUT	INPUT TO	FREQ. IN MC.	METER POSITION	METER READING OR DB.
Noise	Antenna	-	1	-0.1 to -1
Noise	Antenna	-	2	-18 to -40
Noise	Antenna	-	4	*0
Noise	Antenna	-	5	-12 to -16
Noise	Antenna	-	6	-12 to -40
0.5 or less	Antenna	F_c	DB Meter	20 db. (quieting)
6.0	Antenna	F_c	1	-2
2.5 14.0	Pin 1 of V 101 1st RF	F_c F_c	DB Meter 1	20 db. (quieting) -2
3.8 30.0	Pin 1 of V 103 1st Mixer	12.0 12.0	DB Meter 1	20 db. (quieting) -2
5.0 150	Pin 1 of V 104 1st IF	12.0 12.0	DB Meter 1	20 db. (quieting) -2
5000	Filter	.455	1	-5
2000	Pin 1 of V 106 2nd IF-1	.455	1	-5
150,000	Pin 1 of V 107 2nd IF-2	.455	1	-5

*A meter reading of up to ±1 ua of zero is allowable without any degradation.

NOTE

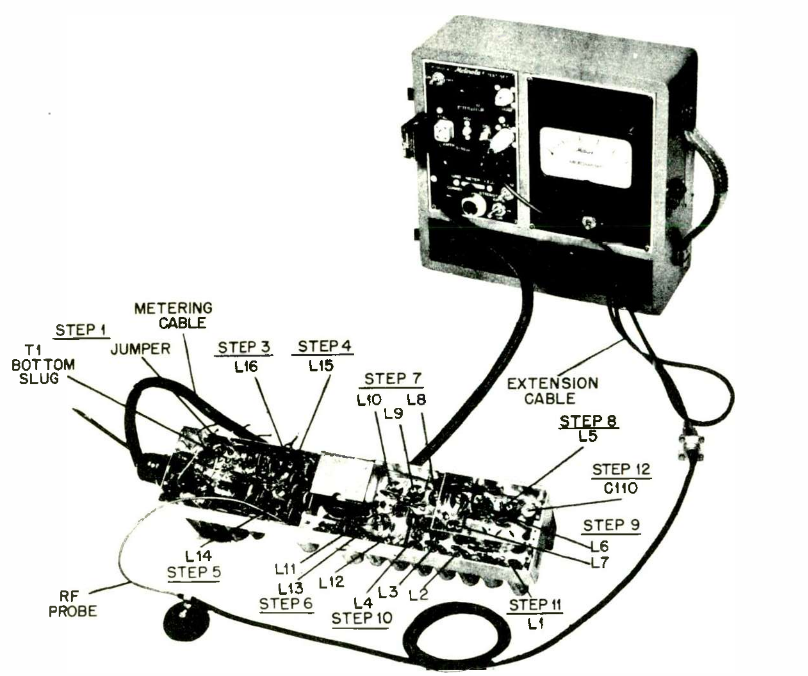
A Model T1034A Signal Generator (or equivalent) with output cable should be used when taking readings on V101, V103, and V104. A Model 65B Signal Generator with a 30 ohm terminated output cable was used when taking all other readings.

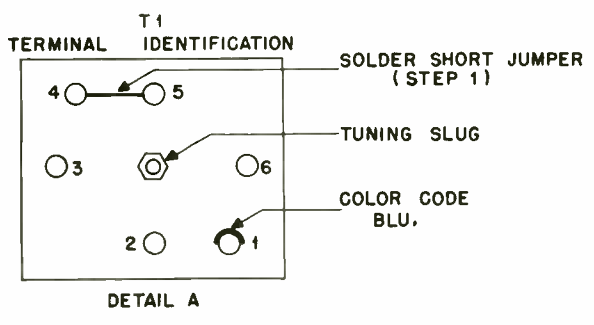
FIGURE 6

COMPLETE BENCH ALIGNMENT PROCEDURE FOR MOTOROLA SENSICON "G" RECEIVER

HOW TO SET UP THE P-8501-A TEST SET FOR DISCRIMINATOR AND 455 KC. I. F. ALIGNMENT

1. Set the REC.-XMTR.-0-50 UA. switch to the REC. position.
2. Plug a 455 kc. crystal into the two-pin crystal socket.
3. Set the GRID CURRENT-METER-FIELD STRENGTH selector switch to the GRID CURRENT position.
4. Set the ATTENUATOR control for maximum output (10).
5. Place the test set ON-OFF switch in the ON position. (Test set operates on internal battery. Conserve battery life by keeping switch OFF when set is not in use.)
6. Adjust the frequency control (ADJ) for a maximum meter reading.
7. Set the ON-OFF switch to the OFF position.
8. Set the GRID GURRENT-METER-FIELD STRENGTH switch to the METER position.
9. Plug the test set metering cable into the METER receptacle on the receiver chassis.
10. Connect one end of the test set extension cable to the RF OUTPUT jack on the test set. Connect the other end of the extension cable to the RF probe cable.





DETAIL A

HOW TO SET UP THE MODEL 80 SIGNAL GENERATOR FOR 12 MC I.F. ALIGNMENT

1. Couple the signal generator output loosely to the grid (pin 7) of V105. Couple just enough input to give a small meter reading.
2. Set the test set selector switch to position +4 or -4. Set the ON-OFF switch to the ON position.
3. Set the signal generator frequency for approximately 12 mc.
4. Locate the exact 12 mc. point by rotating the generator dial back and forth around the 12 mc. setting until you obtain a meter reading of exactly zero (position 4). The meter reading should go above and below zero as the dial is rotated. Leave the generator set for zero meter reading. Make sure the signal remains constant throughout the alignment (generator may drift).

PRIVATE LINE RECEIVER
BENCH ALIGNMENT CHART
FIGURE 5

STEP	STAGE, TEST CONDITIONS AND PROCEDURE	ALIGNMENT FREQUENCY	ADJUSTMENT	METERING	
				SWITCH POS.	READING
1	DISCRIMINATOR PRIMARY—Solder a short jumper across terminals 4 and 5 of the discriminator secondary coil (see DETAIL A, lower left). Set up the P-8501-A Test Set as described in the left hand column. Place the test set selector switch in position 1 and set the ON-OFF switch to the ON position. Move the RF probe around near pin 1, V106, until the meter reading is at least 15 ua. Secure the probe in its position and place the selector switch in position 5. Loosen the locknut of the T1 bottom slug adjustment screw, adjust the slug for maximum meter reading and tighten the locknut while holding the slug in the position of maximum meter reading. Unsolder the jumper.	455 kc., sharp tuning	T1 bottom slug	5	Maximum
2	DISCRIMINATOR SECONDARY—With the RF probe placed as in step 1 adjust the top slug of T1 for exactly zero meter reading (selector switch in position +4 or -4).	455 kc., sharp tuning	T1 top slug	+4 or -4	Zero
3	455 KC. I. F. COIL L16—Place the RF probe near the input to the 455 kc. I. F. filter (see illustration). Couple the signal loosely so that an increase of signal strength will produce a linear increase in meter reading (switch in position 2). Secure the probe in position to keep the input at a constant level. Adjust L16 for a maximum meter reading with the switch in position 2.	455 kc., sharp tuning	L16	2	Maximum
4	455 KC. I. F. COIL L15—Couple the signal to the I. F. filter so as to obtain a maximum reading of approximately 5 ua. with the selector switch in position 1. Adjust L15 for a maximum reading.	455 kc., broad tuning	L15	1	Maximum
5	455 KC. I. F. COIL L14—Use the same conditions as in step 4. Adjust L14 for a maximum meter reading. Place the test set ON-OFF switch in the OFF position and remove the RF probe.	455 kc., sharp tuning	L14	1	Maximum
6	12 MC. I. F. COILS L13, L12 and L11—Set up the Model 80 signal generator (or equivalent) as described below the illustration. After adjusting the signal generator set the test set selector switch to position 1 or 2 and couple the generator output to the grid (pin 1) of V104. The signal must be coupled loosely so that an increase of signal strength produces a linear increase in meter reading (position 1 or 2). Adjust L13, L12 and L11 for a maximum meter reading with the switch in position 2.	12 mc., sharp tuning	L13, L12 and L11	1 or 2	Maximum
7	12 MC. I. F. COILS L10, L9 and L8—Follow the same procedure as in step 6 except couple the signal to the grid (pin 6) of V103 and adjust L10, L9 and L8.	12 mc., sharp tuning	L10, L9 and L8	1 or 2	Maximum
8	FIRST OSCILLATOR COIL L5—Uncouple the signal generator. Position the ceramic trimmer, C110, so that the screwdriver adjustment slot is parallel with the length of the receiver chassis (see illustration). Adjust coil L5 for a maximum meter reading with the selector switch in position 6. On two-frequency receivers be sure that the F1-F2 switch on the control head is in the F1 position while adjusting L5. Then repeat the procedure with the switch in the F2 position while adjusting trimmer C204 and coil L201.	Receiver crystal frequency, sharp tuning	L5	6	Maximum
9	MULTIPLIER COILS L7 and L6—The signal generator must be set for the exact carrier frequency to be received. To do this follow the procedure outlined below the illustration except select the carrier frequency instead of 12 mc. and couple the signal to pin 6 of V103 instead of pin 7, V105. With the generator output coupled loosely to pin 6, V103, adjust L7 and L6 for maximum meter reading (position 1 or 2).	Carrier frequency, sharp tuning	L7, L6	1 or 2	Maximum
10	RF COILS L4, L3 and L2—Keep the signal generator set for the carrier frequency as in step 9. Couple the signal loosely to the grid (pin 1) of V101. Adjust L4, L3 and L2 for maximum reading (position 1 or 2).	Carrier freq., sharp tuning	L4, L3 and L2	1 or 2	Maximum
11	ANTENNA COIL L1—Connect the signal generator output to the antenna receptacle on the receiver chassis. Use a 6 db, 50 ohm, attenuation pad between the generator and the receiver input. Adjust L1 for maximum reading.	Carrier freq., sharp tuning	L1	1 or 2	Maximum
12	FREQUENCY CHECK—Transmit the carrier frequency from the transmitter which this receiver is normally intended to receive. A zero meter reading indicates that the receiver is on frequency. Adjust trimmer C110 to obtain a zero meter reading. Check the final setting by rotating C110 back and forth while observing the meter. The reading should go above and below the zero point as the trimmer is rotated. Set C110 for exactly zero meter reading. On 2-frequency model set switch to F2 position and adjust C204 for zero meter reading.	Carrier freq., sharp tuning	C110	+4 or -4	Zero
13	IGNITION NOISE ADJUSTMENT—Install the receiver in the vehicle. Start the vehicle engine and allow it to run while making the adjustments. Turn the receiver ON and allow it to warm up for five minutes. Radiate a carrier frequency signal from a transmitter, signal generator or test set (see test set instruction manual). The signal should be just strong enough to produce quieting (20 to 30 db). Turn VOLUME control on control head to normal usable level. Plug the test set metering cable into the METER receptacle on the receiver. Set the selector switch to position 2 and note the meter reading. Adjust coil L14 very slightly to reduce audible ignition noise. DO NOT reduce the meter reading more than one-half microampere.	Carrier freq., slight adj.	L14	2	Reduce audible noise

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A TWO-WAY RADIO COMMUNICATIONS TRAINING PROGRAM

LESSON MA-4
MAINTENANCE

Trouble Shooting In General

MOTOROLA TRAINING INSTITUTE

LESSON MA-4
MAINTENANCE

Trouble Shooting In General

—one of a series of lessons on two-way FM communications—

MOTOROLA TRAINING INSTITUTE
4501 W. AUGUSTA BLVD., CHICAGO 51, ILLINOIS
APPROVED BY THE STATE OF ILLINOIS
DEPT. OF REGISTRATION AND EDUCATION

PREFACE

This is one lesson of a complete Motorola Home-Study Course which presents to the Service Technician both the principles of operation and the maintenance of two-way FM radio systems. The program covers mobile, portable and base station equipment, including the latest transistorized units.

GENERAL TROUBLE SHOOTING

LESSON MA-4

TABLE OF CONTENTS

NOTICE

Diagrams and figures referenced in text are "fold-outs" in back of each lesson, for use while studying. The Examinations are also there.

In the event of disaster, radio invariably remains as a reliable method of communications. Civil Defense organizations throughout the country have established extensive two-way radio networks in preparation for all emergencies.

GENERAL TROUBLE SHOOTING

Lesson MA-4

Introduction

It should be remembered that trouble shooting is but one phase of equipment maintenance. Trouble shooting assumes that some piece of equipment in the communications system has already become faulty so that normal contact is not possible or is not reliable.

In addition to trouble shooting, there must be preventive maintenance of electronic equipment. This includes general inspection, equipment tests, and certain required frequency and deviation checks.

In this assignment we will be concerned only with that phase of maintenance which might be classified as "emergency" maintenance, wherein a system or some portion of a system is not functioning properly and must be placed in operation "as soon as possible." We will be concerned here with general procedures only; specific instructions for trouble shooting the receiver and transmitter will be given in the assignments which follow.

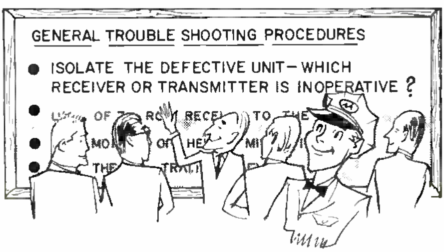
General Procedure

The complete trouble shooting procedure may involve as many as six steps to make certain that proper corrective measures have been taken, and that the system has been restored to normal operation. In certain instances, the nature of the trouble may simplify these steps or even eliminate one or more of them. This will be determined by the circumstances of each situation.

The first step is to determine where the fault lies. For example, a police squad car pulls up to your shop and the operator complains that his rig is dead. A check of the system may show that the transmitter is okay (the base station hears the squad car signals). However, the squad car operator does not hear the base. This indicates either (1) a faulty receiver in the squad car, or (2) a faulty transmitter at the base. By opening the squelch, a quick check may be made on the receiver. If no noise is heard, the fault is probably in the receiver; if normal noise is heard, the trouble could still be in the receiver, but it might also be at the base transmitter. If there are other squad cars in the system, a check on the operation between the base and one of the other cars will immediately isolate the trouble.

The important fact to be recognized is that the trouble must be definitely isolated to some particular unit of the system before any one unit is subjected to a detailed analysis.

Assume that the receiver is at fault. Without removing the receiver from its case, a Motorola test set may be used to make a general check of the unit. Again it is possible that the trouble might not be in the receiver, but in the power supply. In some models, the transmitter and receiver operate from different sections of the supply, or even from different supplies.



Make Complete Checks on the Operation of the Entire System.

After the fault is definitely isolated to a particular unit, the next problem is to determine which stage or section within the unit is at fault.

The next step is to find the defective component (or perhaps the control or circuit that is misadjusted). This may consist only in replacing one or more tubes, or it might require the removal of the chassis for further inspection on the test bench. In the latter case, additional test instruments (voltmeter, ohmmeter, signal generator) are usually required in order to determine the exact trouble.

After a fault has been discovered, determine the proper corrective measures. If a poor connection or broken wire is found, the procedure is obvious enough. Where a component is defective, the problem is one of correct replacement. More will be said about this later.

After the trouble is corrected, the individual unit is checked for operation (correct meter readings, sensitivity, power output, etc.). It is then placed in the car and its operation with the rest of the system is verified.

Isolating the Defective Unit

In any trouble shooting procedure, considerable time will be saved by quickly isolating the defective unit. Knowledge of the normal operation of the entire system will furnish the technician with a definite idea of the possible cause of trouble. Thus, in order to provide intelligent service, the technician must be familiar with the operational characteristics of the system.

In a typical two-way communications system the base station, as the dispatcher, controls the traffic of the mobile units. In order to have communication between vehicles, the same frequency is used for all the transmitters and receivers in the system. The mobile vehicles, let us assume, do not normally operate in extreme fringe areas but are close to the base station---the signal is thus normally stronger than necessary, and there is plenty of system "reserve."

These vehicles, however, may occasionally enter areas where communications from car-to-car is not 100% reliable. This may be due to foliage, high buildings, or other obstacles. Let us further assume that the serviceman makes a routine check each month of each transmitter and receiver, and that he regularly corrects all malfunctions such as low power output in the transmitters or poor sensitivity in the receivers.

Let us now suppose that car No. 1 comes to your shop and the operator complains that, although he is able to hear the base station, he cannot "talk back." This situation is the same everywhere, even in good areas, which eliminates the possibility that the car might have been in a "dead spot." Investigation shows that the base station has normal in-and-out traffic with the other mobiles; hence, the trouble is not in the base station receiver. The fault seems to be with the mobile transmitter in car No. 1. This is confirmed by the operator of car No. 2, who states that once, when car No. 2 was about a block away from car No. 1, the operator of car No. 2 heard car No. 1 trying to talk to the base. As soon as car No. 2 was farther away from car No. 1, the signal died out. We can be reasonably sure now that the output of the transmitter is very low. The Motorola test set may be used for further checks on the operation of the unit.

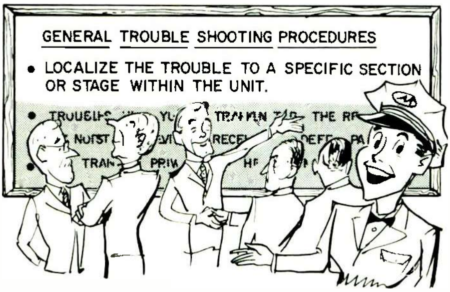
As another example, let us assume the same general complaint from car No. 1---no contact from the car to the base. The other cars report, however, that they hear car No. 1. Moreover, the other cars have been experiencing the same trouble---they can't talk back to the base. The trouble now seems to be associated with the base station receiver.

In both these examples the basic complaint was the same --- no contact from car No. 1 to the base. In the first instance, additional information indicated that the trouble would be found in the transmitter at car No. 1. In the second instance, however, the trouble seemed to be at the base receiver. This illustrates the importance of making a complete check of the operation of the entire system before deciding that any particular unit is defective.

The solution of many problems is not always so obvious. It is then necessary to make further checks before the trouble can be isolated to a particular unit. Or, the trouble may be due to poor operation of several units---the transmitter power may be weak and at the same time the sensitivity of one of the receivers may be poor.

General Check of Individual Units

Where the symptoms are inconclusive and the fault cannot be directly assigned to one unit within the system, it may be necessary to make an over-all check of all the suspected units.



The Test Set is Helpful in Localizing a Fault Within the Unit.

Where a system has some reserve, the output of a transmitter may gradually decrease without causing any particular trouble. This reserve is desirable, for it obviates the necessity of servicing the system every time one unit becomes a little weak. Where the output of a base transmitter has decreased and, at the same time, the sensitivity of one or more mobile receivers has also decreased, normal contact may no longer be possible. In such cases, the obvious answer is to restore all units to their normal operating condition. The transmitter as well as the receiver (s) should be returned to normal power output and full sensitivity, respectively.

For trouble shooting the transmitter, a Motorola test set and wattmeter are among the most useful test instruments. By indicating the power output, the wattmeter gives an immediate check of the over-all operation. If the output is low, the test set will indicate which stage is not up to par, and further checks may then be made. If the power output seems to be normal, the operating frequency may be checked, provided another receiver in the system can be monitored. With the switch on the Motorola test set placed in position 4 of the receiver, the reading will then indicate whether or not the incoming signal is "on channel." This reading is normally zero. If the transmitter is off frequency, a frequency meter should be used to correct the condition.

The power output of the transmitter may be measured by means of a thru-line wattmeter, either with a dummy load or with the antenna system connected. This unit shows the amount of power traveling each way in the transmission line and gives a good indication of how much of the power going to the antenna is actually being radiated into space. Unless the reflected power is very low in comparison to the forward power, the poor operation of a system may be attributed to the antenna or transmission line.

In order to make a quick check of the receiver, it is important to have a Motorola test set and an RF source of the correct frequency. Using this test set, meter reading at positions 1 and 2 will indicate the operation of the front-end of the receiver; position 6 (in most receivers) can be used to check oscillator activity. These readings are taken with no signal applied. With a signal of the correct frequency applied, the discriminator secondary (position 4) should read zero. These readings, together with the noise heard when the receiver squelch is open, can be used as a general check of receiver operation. If the operation seems to be normal, a signal generator can be used to determine the receiver sensitivity. The generator used for this purpose must have an accurate calibration of its output voltage.

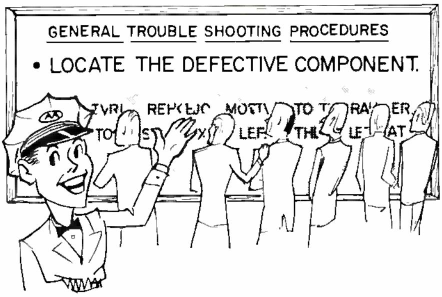
The output of the transmitter power supply can be measured by means of the test set. Low supply voltages can well be the cause of low power output from the transmitter or low sensitivity at the receiver. In addition, the possibility of a weak battery in the vehicle must also be considered, for this will result in a low supply voltage both to the receiver and to the transmitter. Power supplies should never be overlooked when trouble shooting individual units.

Locating The Defective Part

Having determined the defective portion of the unit, the technician is now faced with the problem of finding which particular component within the complete unit is the source of trouble. He knows the particular stage or section which is at fault--he must now determine which component is defective. The experienced serviceman knows that most troubles are due to defective tubes, so his first procedure is to substitute new tubes for those which might be causing trouble. At the same time, the test set is plugged into the unit and the effect of tube substitution upon the various readings is noted. If a new tube does not restore normal operation, the next step will vary according to the nature of the fault and according to whether the unit is a receiver or a transmitter.

When working on a transmitter, the serviceman starts with the oscillator and proceeds through each successive stage until the exact location of the trouble is determined. Each stage is checked by means of the nearest meter position. Watching these readings, he adjusts each circuit until the proper peak indication is obtained when tuned through resonance; it may also be necessary to check the neutralization and the coupling in some units. This procedure should definitely pinpoint the defective stage.

If the tube is good and the tuned circuits seem to show normal peaks, it may be necessary to take voltage and resistance readings. As a final step, the serviceman should try substituting parts in the suspected stage. This procedure is not infallible, of course, and the test may prove inconclusive, but by following a logical procedure the defective part will eventually be located.



Voltage and Resistance Tests Usually Provide this Answer.

When working on a receiver, the procedure may be somewhat different, because there is no input to the receiver except from a transmitter or signal generator. Again, the procedure may vary according to the symptoms found in the preliminary checks. A signal generator can be used for stage-by-stage sensitivity checks and this is one method of definitely isolating the fault to a particular stage. These checks are made by adjusting the tuned circuits to resonance and noting the peak indications. When the trouble is isolated to a particular section of the receiver but not to a specific stage, it may become necessary to take voltage and resistance readings. The exact procedure will be governed by the symptoms.

Where the antenna system is the source of trouble, the problem may be simplified because of the limited number of parts. If the antenna is on a high tower, however, the service procedure may be difficult. The previously mentioned thru-line wattmeter may prove a very helpful instrument for determining whether the trouble is in the antenna or in the transmission line. A comparison of the forward and reflected power measured both at the beginning and at the end of the transmission line (if convenient) will usually show which is at fault, the antenna or the line.

Parts Replacement

We have now reached the point where the serviceman must replace a defective part with a good one. There are a number of components within the equipment with ratings which are not considered critical (a bypass capacitor can often be made larger without changing the operation of the unit). In most cases, however, the serviceman must observe the exact value and rating of the part being replaced. Wherever possible, the new part should be identical to the old one, and secured from the manufacturer of the original part. If this is impossible, the replacement should at least have an identical rating. For example, the wattage rating of a resistor must be the same or higher than that of the original. If the part is a capacitor, the voltage rating must be the same or higher. There are many other important factors in connection with replacement parts besides wattage and breakdown voltage. If a resistor has a 5% tolerance, for example, the new unit should also be within 5% of the indicated resistance. If the defective capacitor has certain ratings with regard to temperature and capacitance, the replacement must have the same ratings.

It is important when making replacements to position the new part in the exact same location as the original, and to be careful that the wiring is not disturbed. This is most important, of course, in the front end of the receiver. A coupling capacitor in the RF stage to the mixer, for example, may cause oscillation unless it is positioned close to the chassis.

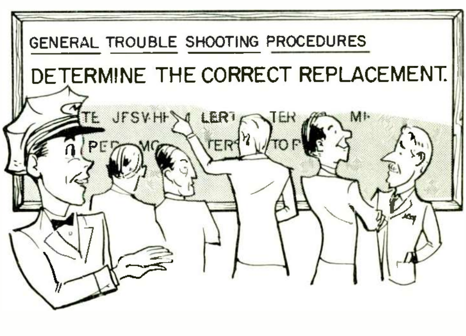
Before replacing a defective part, the actual cause of the defect should itself be removed. In many instances a bypass capacitor may have shorted, causing a resistor to burn out. The short in the capacitor may easily go unnoticed while the burned out resistor is found at once by visual inspection. If the shorted capacitor is left in the chassis when the resistor is replaced, the new resistor will also burn out.

Recheck and System Testing

After a unit has been repaired, its operation should be checked and, if possible, it should also be bench-tested for some period of time to make sure that it will continue to operate.

After the unit has been thus tested for normal operation, it can be installed in the vehicle and a complete check made on its operation within the system. It is most important that the receiver or transmitter be "netted" with the rest of the system.

This concludes our discussion of general trouble shooting procedures.[1] The use of most trouble-shooting instruments can be explained more specifically, of course, when included in a more complete analysis of the receiver or transmitter. The following assignments on receiver and transmitter servicing will contain this information. The voltmeter and ohmmeter can be discussed at this time, however, and the remainder of the assignment will be devoted to explaining the use of these instruments. First, however, it is well to point out that we need not know the internal circuitry of either of these instruments. It is far more important to know how to use them intelligently.



Get Replacement Parts From the Manufacturer Whenever Possible.

1. See Test Methods, section 1, pages 1-2 and section 3, pages 1-5.

Using the Voltmeter

The voltmeter is an arrangement of resistors and a meter (sometimes vacuum tube controlled for greater sensitivity) which indicates the voltage or difference of potential existing between two points of a circuit. Because the voltmeter does not have an internal source of voltage, the equipment being measured must be "ON" when voltage tests are being made. The meter is connected in parallel with the particular portion of the circuit being tested. Thus, the circuit being measured is not broken, nor is anything disconnected for this test.

It must be remembered that the meter is a resistor as far as the circuit being tested is concerned, and when the meter is connected we are actually placing a resistor across the circuit. In most circuits, the high resistance of the VTVM (vacuum-tube voltmeter) does not noticeably affect the circuit operation. In certain circuits, however, the presence of the meter does change the circuit operation and it is not impossible for a "dead" receiver to start operating when the meter is connected for a voltage check! We are now ready to look further into the use of the voltmeter in testing procedures.

Figure 1 shows the circuit of the last IF amplifier stage and the first limiter stage in a typical communications receiver. We are assuming that the signal is lost at the grid of the limiter - - - there is no meter indication at this grid. Tube replacements have failed to restore operation, and the receiver has been brought to the test bench for repair.

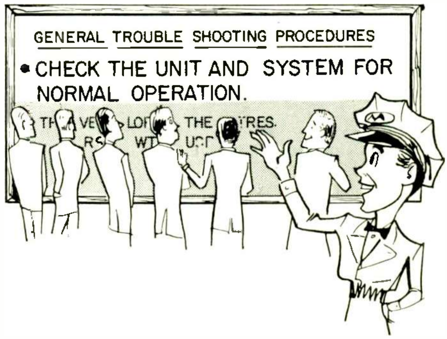
The voltmeter tells us that the B supply voltage, between B plus and ground is normal. A further check at points C and D, however, shows no voltage present. A check at point E is also zero with respect to ground. The logical conclusion is that resistor R3 is open. The resistor may be replaced, of course, but additional tests are necessary to make sure that some other defect in the circuit is not causing the resistor to burn out. Suppose that when the resistor is replaced and the power turned on, the replacement unit also quickly overheats.

Several procedures are now possible. With the power off, an ohmmeter can be connected between point E and ground. Zero resistance would mean that C4 is probably shorted, or there could be a short between plate and cathode of the tube. (The tube can be removed to determine if it is defective.) A wire may have become shorted by rubbing against some sharp point, or a tie-point may be shorted in some manner. These shorts can be located by a visual inspection of the parts and wiring.

If operation seems to be normal after the resistor is replaced and there seems to be no reason for the burning out, we must look elsewhere for a logical explanation. The tube might have been intermittently shorted; this could burn out a resistor. If this seems to be the only explanation, it might be well to replace the tube, for there is a good chance that the tube may short again in the future.

While making the original voltage checks on the circuit of figure 1, if the voltmeter had been placed across the terminals of resistor R3, there is a good chance that the receiver would have started to operate, although the output would have been below normal. This would be because the resistance of the meter, being substituted for R3, completed the path from B plus to the plate and screen circuits of the tube. Even though the resistance may be many times higher than the normal circuit value, the circuit will still operate sufficiently to allow some signal to get through the receiver. When nonelectronic meters having low sensitivity are used, the low-voltage scale may actually restore normal operation when the meter is placed across the resistor terminals.

Here is another problem in connection with the circuit of figure 1. Let us suppose that the receiver is inoperative and that the trouble has been pinpointed to the IF stage--- the tube apparently is not conducting. This possibility seems to be confirmed by the voltage readings; screen and plate voltage readings are taken at points C and D, respectively, and these readings are just a little higher than the

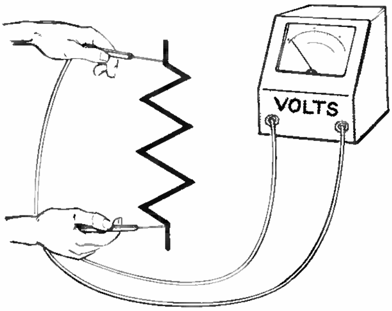


The Final Proof of any Repair is by Reestablishing Normal System Operation.

recommended values, but the meter reads zero at the grid of the tube.

The tube is replaced, but the readings remain unchanged! Further voltage checks are taken with the voltmeter placed between plate and cathode. The reading is zero. Obviously the cathode circuit is at fault, and the specific trouble would seem to be an open cathode resistor. There can be no plate current if the cathode resistor is open, and an open cathode would also explain the zero reading previously obtained at the grid, for there should be some grid current even if there were no plate voltage, provided the cathode circuit is intact.

The voltmeter is now connected directly across the cathode resistor. If the cathode is open, this will have the effect of substituting the high resistance of the voltmeter for that of the cathode resistor. Even with this high resistance there should be some plate current, since cathode bias alone cannot entirely cut off plate current. Again our suspicions are confirmed; the receiver now operates, although the output is below normal. As a further quick check, the cathode may be momentarily shorted to ground.



Voltage Measurements are Always Made by Placing the Voltmeter in Parallel with the Unit Being Tested.

Our diagnosis can now be verified by turning off the power and placing an ohmmeter directly across the cathode resistor, between point A and ground. The open resistor should be immediately evident.

The tube should be removed from its socket when making this ohmmeter test, or it should be allowed to cool off, at least; otherwise, if the tube is still warm, care must be taken to connect the positive lead (internal battery) of the ohmmeter to the cathode. If the ohmmeter connections are reversed (and if the tube is still hot), the tube will conduct grid current through the meter, which might lead to the conclusion that there is resistance in the circuit even though the cathode is actually open.

Tips On Using the Voltmeter

The first thing to remember when using a voltmeter is that this instrument is always placed in parallel with some portion of an operating circuit in order to determine the voltage drop at that portion of the circuit. When making DC voltage measurements, the meter polarity must always be observed. The positive test prod of the meter is placed at the point nearest the positive side of the source; the negative test prod is placed at the point of the circuit nearest the negative terminal of the source.

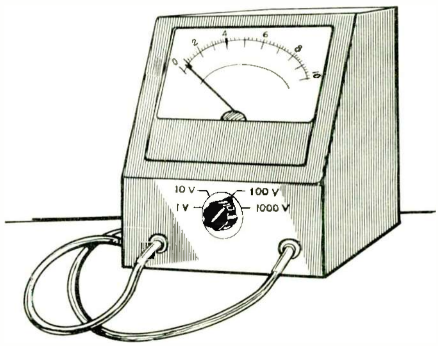
Unless the supply voltage is known, it is always best to start at a high scale on the voltmeter. If the reading is too low, the meter may then be switched to a lower scale. If the highest voltage in a unit is about 200 volts (as in a receiver), it is not necessary to start at the 1000-volt scale; the 300 volt range is high enough.

When a VTVM is used, it is permissible to switch to the scale which provides the most readable meter deflection. A low sensitivity meter, however, will readily upset the operation of some circuits in many cases, actually changing the circuit voltages while the meter is connected. This meter will have the least effect upon the circuit when the higher ranges are used. On the ten-volt range, for example, a meter may offer as little as 10,000 ohms of internal resistance.

When making voltage tests, the entire circuit operation must be studied and understood if the meter readings are to be intelligently interpreted. Perhaps we can best illustrate this by an example. Figure 2 shows the circuit of a typical voltage amplifier --- actually, the noise amplifier circuit of a particular Motorola receiver. A VTVM shows about 200 volts for the B supply, which is normal. The recorded plate voltage (plate to ground) is nearly 200 volts, and the screen voltage is about 100 volts. The cathode voltage (between cathode and ground) is considerably higher than normal, and there is no voltage reading at all between plate and cathode, nor between screen and cathode. This indicates that the tube is not conducting.

The voltmeter indicates zero volts across R6, but 100 volts across R5. The tube might be nonconductive, but there is a greater probability that the cathode circuit may be open, since you will remember that the voltage between both screen and plate (with respect to the cathode) was zero. This indicates an open cathode circuit rather than a bad tube. A further check results in obtaining a voltage reading across R3 in the cathode circuit, but not across R2. The zero voltage across R2 means that the cathode circuit (not R2) is open. The reading across R3 indicates that R3 is open, the circuit now having been completed by the meter! By replacing R3, the circuit is restored to normal.

This analysis may be more easily understood if we consider the complete plate circuit of figure 2 independently, as shown in figure 3. The tube can be regarded as a resistor, and it is shown as Rt. There are thus four series "resistors" between B plus and ground. Let us assume that one of these resistors (R3) is open. The circuit is incomplete and there is no current through any of the resistors. Also, since there can be no voltage across the resistors, the circuit is still incomplete even when the meter is placed across either R6, Rt, or R2, and the voltage reading must still be zero. When placed across R3, however, the meter completes the circuit and records a voltage. This is exactly what happened in the analysis above, the reading across R3 indicating an open resistor.



The Highest Meter Range Giving a Readable Deflection Provides the Most Accurate Voltage Readings.

A question may arise in connection with the 100 volts originally recorded at the screen when the tube was not conducting. If there was no current through the tube, you might ask, why is there a voltage drop across the screen resistor? An examination of figure 2 will show that resistors R4 and R5 form a voltage divider between B plus and ground. This will result in a lower potential at the screen, independent of screen current. This will be further decreased when the screen draws current through R5, due to the increased voltage drop across R5.[2]

AC Voltmeter

The AC voltmeter must be used when measuring AC voltages. The AC voltmeter is similar to the DC voltmeter, as far as the foregoing instructions are concerned, but no consideration need be given to the polarity of the AC test leads. Any AC measurements made by the serviceman are almost exclusively of the low-frequency type, and in this discussion we will be concerned only with such AC measurements.

While other types of AC meters are available, most of those used by the serviceman include a rectifier which changes the AC to a comparable DC and then indicates the amount of DC on the meter. Some use an amplifier stage or two to give the meter greater sensitivity.

The meter may respond to either the peak, the RMS or the average value of AC, although in most cases the meter indicates the RMS value. In using his meter, the technician should know whether the reading corresponds to the RMS (effective) or to the peak value. The dial of the meter is usually marked according to what is recorded.

Resistance Testing

An ohmmeter is essentially a source of voltage (a battery) in combination with a meter and various current limiting resistors. It is used to determine whether a particular component or circuit will conduct DC. Knowing the current through the part or circuit being measured, and with a fixed voltage source which is also known, the resistance can be read directly from the calibrated scale of the meter.

Because the ohmmeter contains its own source of voltage, there must be no other voltage used in connection with the equipment being measured. Furthermore, sensitive meters and other low-current devices must be removed before applying the ohmmeter. While this latter precaution is seldom necessary in two-way equipment, the power must always be removed, and all large capacitors discharged. Large capacitors, particularly electrolytics may retain a charge long after the power has been turned off. If such capacitors are allowed to discharge through the ohmmeter, the meter movement may be damaged.

When using the ohmmeter to analyze circuits or components, it is particularly necessary to take the entire circuit into consideration.

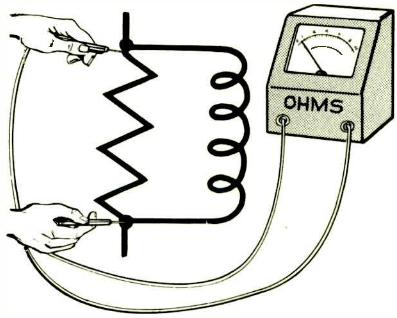
2. See Test Methods, section 2, pages 5-11.

An ever recurring problem when using the ohmmeter is the existence of DC paths in parallel with the component or circuit being measured.

The circuit of figure 4, showing the second limiter and last audio output stage of a Motorola receiver, is an example.

Finding that the voltages of the second limiter are not correct, and suspecting the existence of trouble in the grid circuit, the serviceman makes a quick resistance check between grid and ground. The meter shows that there is a conductive path. This information alone is not sufficient, however, for grid resistor R1 may be open; the reading may be due to the circuit in parallel with R1, composed of R4 and R5. Now, the grid-ground reading should be approximately 100 k, the value of the grid resistor. The parallel path through R4 and R5, however, has a resistance of 2.5 meg. If R1 is open there is still a complete grid path for DC, it is true, but the extremely high resistance of this "parallel path" may impair the operation of the receiver; it may easily be the cause of the incorrect voltage readings. This illustrates the importance of checking a circuit or component for the correct amount of resistance as well as for an open or short.

Another problem involving the ohmmeter can be illustrated before leaving figure 4. Let us suppose that the receiver is "dead," that is, nothing is heard in the speaker. Let us also suppose that unsquelching the receiver and turning the volume full on doesn't help. Meter readings are taken on the test set and they indicate that the trouble is possibly in the audio stage (although there still is no sound from the speaker, the voltage checks are all normal for the audio output stage). The final deduction is that the output transformer secondary is open.



Parallel Paths Within a Circuit Often Give Erroneous Resistance Readings.

The power is turned off, and we prepare to check the continuity with the ohmmeter. Note, however, that the speaker is in parallel with the transformer secondary. Placing the ohmmeter across the secondary terminals of the transformer would be meaningless in this case. It would still be difficult to know which unit was at fault. While the resistance value of the two units in parallel is lower than that of either unit alone, this resistance is so low that it would be impossible to know which one was open. The only logical procedure in a case like this is to disconnect one of the wires leading to the speaker and then check the two parts separately.[3]

Measuring Leakage In Capacitors

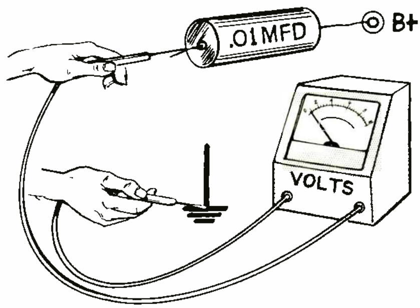
A problem often encountered when trouble shooting communications equipment involves the isolation of capacitors which are not shorted, but are merely "leaky." The defective capacitor, not readily located by a resistance check, may have developed a leakage resistance in the order of one megohm, for example. In many instances, DC voltage changes will occur in the circuits at each side of the leaky capacitor. As a result, the overall operation of the entire unit becomes unsatisfactory.

A leaky capacitor can sometimes be identified by measuring the voltages at each side of the unit. The capacitor in figure 5A may be used to couple any of the audio stages, or it may be used between stages in the IF section. The plate load of the first tube may consist of a resistor (as in figure 5A) or it may be a tuned tank. Some stages may have a large value of resistance, while others may have less than 100,000 ohms--even a few ohms where only a tuned circuit is used. In any case, the change in the voltage at the grid of the next stage is important, because of the change of bias which results. An example will show how this affects the meter readings of the stage.

Let us suppose that the coupling capacitor of figure 5A has a leakage of about 5 megohms, and that the grid resistor (R2) is about 50,000 ohms (47K actually). The leaky capacitor (Rc) thus completes a series circuit between B plus and ground, as shown in figure 5B. The voltage will divide, in this circuit, according to the resistance of the three series resistors. Most of the voltage drop will be across Rc which has 100 times the resistance of R2 and there will be but a few volts across R2 and R1. Thus, a meter placed across R2 will read only a few volts at most, and this may be disregarded as a major source of trouble. Perhaps the leaky capacitor may not be causing much trouble at this particular moment, but there is a strong probability that the leakage will gradually increase to a point where the operation of the equipment is seriously affected. It is thus important to recognize this leakage and replace the unit at once.

In many circuits the signal applied to the grid of the stage produces enough grid-leak bias to make the grid negative with respect to ground, and this leaky capacitor may not be detected; while the leaky capacitor permits the application of some positive voltage from the plate circuit of the preceding stage to the grid, the latter shows a negative voltage due to the large grid-leak bias. By removing the second tube, however, the positive voltage will be readily disclosed. With the tube removed, the grid cannot

3. See Test Methods, section 2, pages 12 and 13.



A Voltmeter in Series With a Capacitor and Connected Between B+ and Ground Gives a Reliable Check for Leaky Capacitors.

draw current and the negative bias is thus removed.

A more conclusive check can be made by disconnecting the grid side of the capacitor from the grid and placing the meter between the loose end of the capacitor and ground. The circuit is shown in figure 5C, where R2 has been replaced by a meter; if the meter is a VTVM, this resistance will now be about 10 or 11 megohms. Most of the resistance of the series circuit is now represented by the meter, and the voltage drop will be greatest across the VTVM.

It is possible that when the meter leads are first connected, the capacitor will be charged by the B+ supply; in this case the meter will show a sharp initial deflection which decreases as the capacitor approaches its full charge. If the VTVM returns to zero voltage (measured on a low-voltage scale), the capacitor is not defective. If the meter has a continuous voltage reading, however, the capacitor is leaky and should be replaced. When making a test of this kind, a high-voltage scale should be used at first so that the initial charging of the capacitor does not damage the meter movement. As the amount of deflection decreases, the meter may be returned to a lower range.

The voltmeter may thus be used to check the relative ability of a capacitor to charge, giving a relative indication of the capacitance itself. The deflection of a given meter is directly dependent on (1) the amount of supply voltage and (2) the capacitance of the unit being checked. Small capacitors, about .001 ufd and lower, do not cause an appreciable amount of initial meter deflection.[4]

4. See Test Methods, section 2, pages 19-25.

STUDENT NOTES

STUDENT NOTES

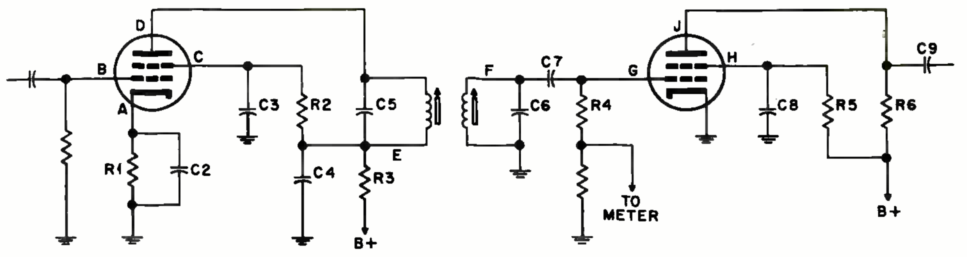


FIGURE 1

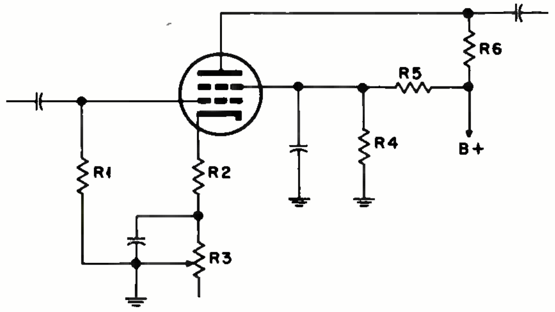


FIGURE 2

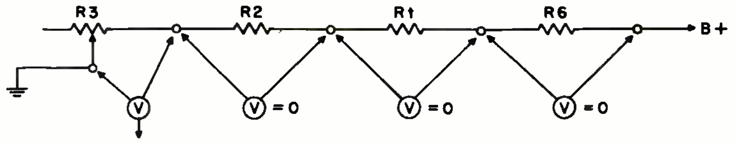


FIGURE 3

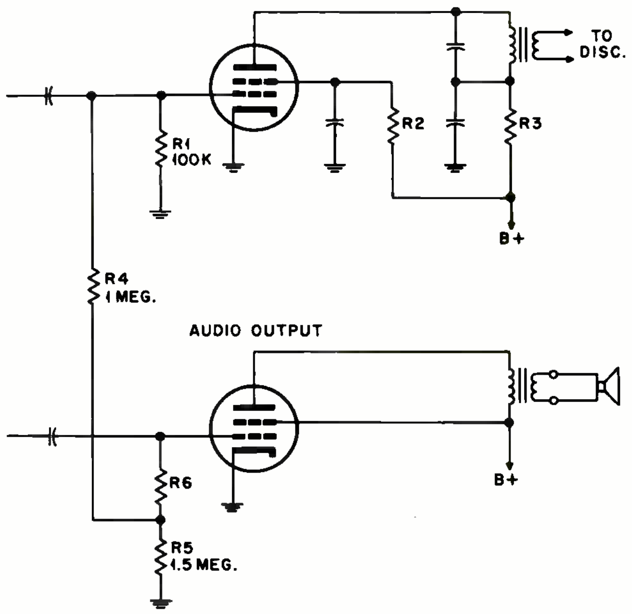


FIGURE 4

FIG A-B REQUIRED FOR? 89-16

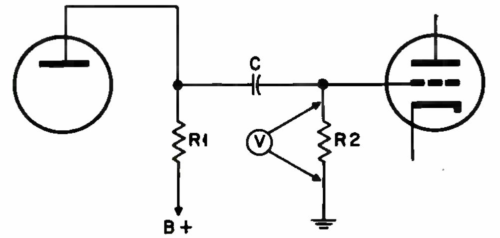


FIGURE 5A

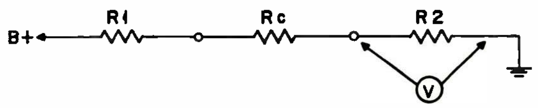


FIGURE 5B

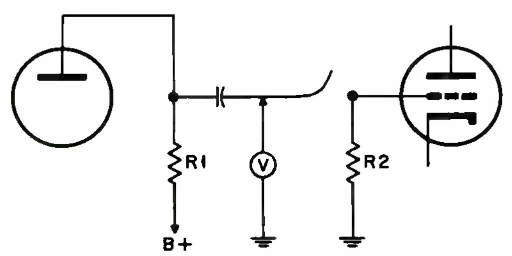
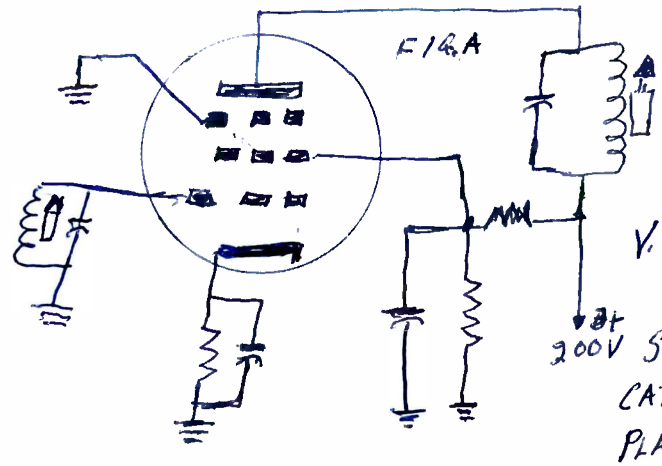


FIGURE 5C

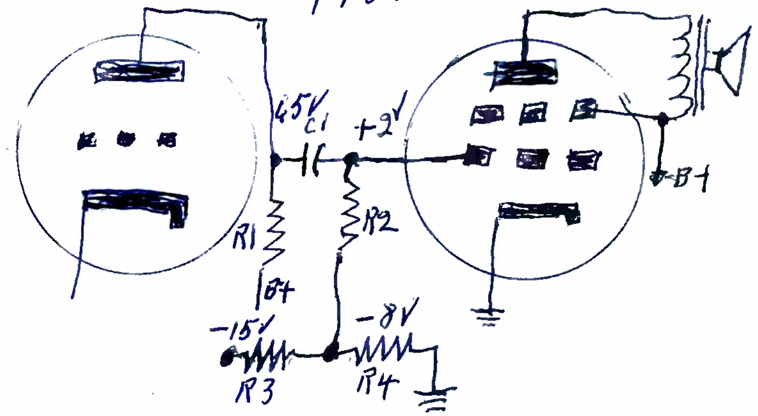
FIG A



V. READING
PLATE to ⏚ = 0
SCREEN to ⏚ = 75V
CATHODE to ⏚ = 0
PLATE to B+ 200V

FIG B

AUDIO OUTPUT



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A TWO-WAY RADIO COMMUNICATIONS TRAINING PROGRAM

LESSON MA-3
MAINTENANCE

Test Sets

MOTOROLA TRAINING INSTITUTE

A TWO-WAY RADIO COMMUNICATIONS TRAINING PROGRAM

LESSON MA-3
MAINTENANCE

Test Sets

—one of a series of lessons on two-way FM communications—

MOTOROLA TRAINING INSTITUTE

4501 W. AUGUSTA BLVD., CHICAGO 51, ILLINOIS

APPROVED BY THE STATE OF ILLINOIS
DEPT. OF REGISTRATION AND EDUCATION

PREFACE

This is one lesson of a complete Motorola Home-Study Course which presents to the Service Technician both the principles of operation and the maintenance of two-way FM radio systems. The program covers mobile, portable and base station equipment, including the latest transistorized units.

TEST SETS

LESSON MA-3

TABLE OF CONTENTS

NOTICE

Diagrams and figures referenced in text are "fold-outs" in back of each lesson, for use while studying. The Examinations are also there.

The large scale activity in constructing a nation-wide system of tollways, turnpikes and freeways has resulted in many new extensive communications systems. The special police and maintenance forces needed to protect and keep up these new traffic arteries rely heavily on two-way radio.

TEST SETS

Lesson MA-3

Introduction

Motorola has developed two test sets, both designed to provide quick and accurate checks on the various receivers and transmitters used in Motorola two-way communications equipment. These test sets are identified by their model numbers, P-8501 (A or B) and TU-546. The TU-546 is the newer of the two, but the P-8501 provides all the tests necessary for aligning and servicing the equipment. In this lesson we shall make a detailed analysis of the circuits within the test set, circuits which enable the serviceman to make all the necessary transmitter and receiver measurements. Let us begin with the P-8501 unit.

Functions Of The Test Set

The P-8501 Motorola test set provides the following specific functions:

1. It meters the important circuits of the receiver. This is essential both for alignment and for the quick isolation of trouble within a particular section.

2. It meters the important circuits of the transmitter. By "viewing" the various circuits of the transmitter, the operation of each stage may be evaluated. In trouble-shooting and in transmitter alignment, this function is essential, providing vital information to the serviceman.

3. It operates as a crystal-controlled signal generator. When equipped with a crystal of the correct frequency, the generator supplies an output which can be used for aligning or peaking the receiver circuits. For the RF circuits, a multiplier stage within the test set supplies the required signal at the channel frequency. For IF alignment, a crystal of the IF frequency is used.

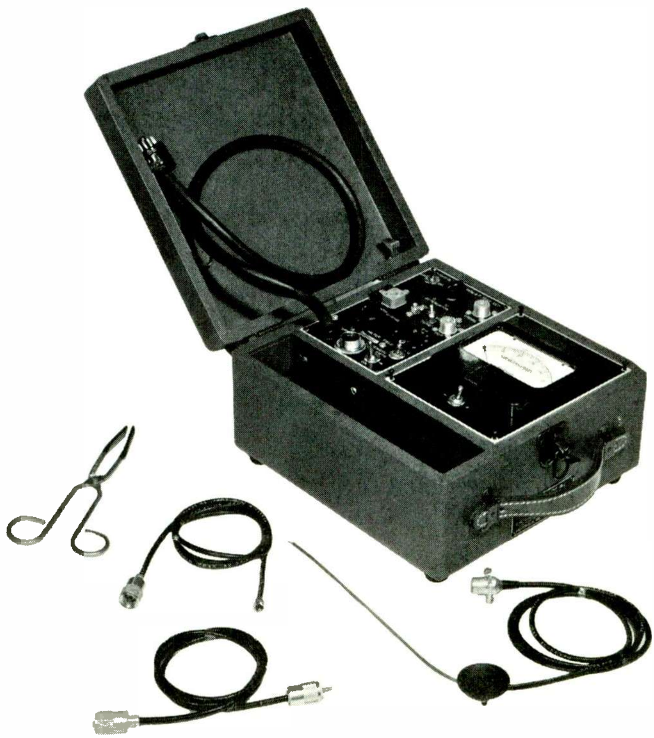
4. It serves as a microammeter. The basic sensitivity of the meter in the test set is 50 microamperes for full-scale deflection. With an internal impedance of 2000 ohms, it takes 0.1 volt to produce full-scale deflection.

5. When used with the Motorola dummy antenna, the test set provides a means of measuring the power output of a transmitter.

6. It serves as a field strength meter. It can be used to measure relative signal strengths radiated from a transmitter antenna.

The Motorola test set is powered by self-contained batteries, and all functions of the unit are regulated by the controls on the front panel. Adapter cables enable the test set to be used with all Motorola equipment. The meter movement is protected by a 1/200 amp. fuse.

Figure 1 shows the front of the P8501 A/B test set. The various switches and controls are identified by numbers, corresponding to those on the schematic diagram (figure 2). Other connections are identified by letters for convenience of reference. The complete schematic diagram may seem complicated, but when the individual circuits corresponding to the various functions of the instrument are considered separately, the analysis can be made with ease. Before studying these



Here We See the Complete Motorola P-8501 Test Set, Including Accessories.

individual circuits, however, let us first examine the various front panel controls.

Function Switch (Grid Current-Meter-Field-Strength)

Designated as S1, this switch may be considered as the function switch. When the switch is in the meter (center) position, the test set can be used for metering the receiver or transmitter. In the GRID CURRENT position (left), the meter is connected so it will measure the oscillator grid current of the signal generator. Thus the meter is used in this position only when the oscillator is to be adjusted. In the FIELD STRENGTH position (right), the test set can be used to measure field strength. The input to the test set is at the PROBE connector (C) for this function.

Rec.-XMTR-0-50 MA Switch

This switch is designated as S4 on the schematic. With the function switch (S1) in the METER position, (as shown in figure 2), switch S4 determines whether the meter is to be used to monitor the receiver, the transmitter, or as a straight 50 ua DC meter.

The Position Switch

Designated S2 on the schematic, this 9-position switch selects the particular receiver or transmitter circuit to be metered. The fifth position is labeled both "PA" and "+4" on the panel. When the test set is being used with a receiver, this position is read as +4; with a transmitter, it is read as PA.

For monitoring either the receiver or the transmitter, the terminals of this switch are connected by means of a cable on the test set to the meter plug, P1. This plug is inserted into either the receiver or the transmitter --- according to which is being metered.

XMTR. On Switch Microphone Receptacle

This spring-loaded switch is labeled S3 on the schematic. It provides for turning on the transmitter, by means of the test set. Because of the spring loading feature, the transmitter will be on only so long as the switch is held at the ON position. A microphone can be plugged into the mike receptacle (E) on the Test Set and used for the same purpose.

On/Off, Attenuator, Adj., Osc. Tune, XTAL, R.F. Out, and 6-12

These controls and receptacles are grouped together in the above heading because they are concerned with the operation of the signal generator portion of the test set. The ON/OFF switch (S6) connects the internal batteries to the oscillator and multiplier stages. Two crystal sockets (A and B) are provided for connecting frequency-control crystals into the oscillator. The generator output is available at the RF OUT. receptacle (D). The amount of RF voltage at the output is controlled by the ATTENUATOR (R9), which varies the output between maximum and zero. The ADJ. (C2) and OSC. TUNE (L1) controls are used in tuning the generator for correct frequency and maximum output voltage.

Filament voltage from the receiver is available for crystals equipped with heaters. The 6-12 switch (S5) provides for the proper heater voltage at the heater. This switch shorts out a series dropping resistor when 6-volt supply is used. With a higher filament voltage (12 volts), the series resistor reduces the voltage to the proper value at the crystal heater.

Meter Reversing Switch

When the service technician wishes to use the Motorola test set for measuring the circuits within a receiver, he first operates the switches as follows: function switch S1 to METER, switch S4 to REC, meter reversing switch (S7) to "—," its normal setting. The various circuits within the receiver may now be metered according to the setting of the position switch (S2). The meter plug (P1) is then inserted into the receiver receptacle. The leads of the various circuits to be measured are already connected to these terminals, within the receiver.

Metering The Receiver

Figure 3 shows the complete circuitry of the receiver metering function. Metering plug P1, to the right, connects into the receiver chassis, and the various circuits of the receiver are then connected to the meter according to the setting of the position switch, S2. The position switch has two decks or sections, designated A and B.

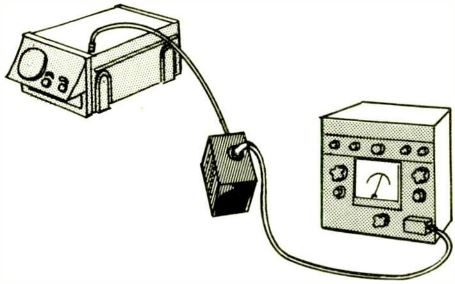
In position 1 the voltage present at plug terminal 1 is applied through section A of the switch, through function switch S1 (in METER position), through the meter reversing switch S7, through the RF choke (RFC2) and through the fuse to the negative side of the meter movement. The positive side of the meter is returned to ground through RFC1 and the meter reversing switch, the function switch (in METER position), the 17.5K resistor, and section B of the position switch, S2. Thus, in position 1 the meter is connected to measure a voltage which is negative with respect to ground.

Positions 2, 3, -4, 5 and 6 of the switch establish the same circuit through the meter as used for position 1. Therefore, these positions are also used for metering negative voltages.

When the test set is used with a receiver, positions 1, 2, and 3 are usually reserved for measuring negative voltages produced by limiting action. This may be in the limiter grid, or in the grids of the preceding IF stage producing limiting action. Position -4 is used to zero the discriminator transformer secondary. We know from our previous study that the discriminator output may be either positive or negative depending upon the tuned secondary; only when the secondary is tuned to its exact center frequency will the reading be zero. If the output should be positive the meter reading will be downward when the switch is in position -4. Under these conditions the meter reversing switch (S7) may be placed in the (+) setting, or the position switch (S2) may be set at "+4." The +4 circuit is the same as that of -4, except the current goes through the meter in the opposite direction.

Position 5 of the meter is used for adjusting the primary of the discriminator transformer to center frequency. Position 6 is used to meter the grid voltage in the high-frequency oscillator; it thus becomes a means of adjusting the oscillator for maximum activity.

With certain Motorola equipment, exceptions will be found in the application of the various switch positions. This is particularly true with the 450-mc line, where position 3 may be used to measure the high-frequency oscillator grid current, the position switch being used for the multipliers following the oscillator.



Used With the Motorola Dummy Load, the Test Set Measures Transmitter Power Output.

In 450-mc equipment a number of multipliers are used to produce the desired harmonic, and these multipliers must be tuned. Several additional multiplier readings are thus required, and for some receivers the necessary connections are made to terminals 7 and 8 of the receiver receptacle with meter plug terminals 4 and 5. With the adapter plug in use, the multipliers are thus tuned in positions -4 and 5, respectively. In other receivers, positions -4 and 6 are used to meter the multipliers. (The schematic of adapter plug appears at the bottom of figure 2.)

Position 7 is used with but a few receivers, which make use of this connection for measuring the B supply voltage. The circuit of figure 3 shows a 20-megohm resistor in series with the meter. Thus, the meter is capable of reading B plus voltage in position

7, full-scale deflection representing 1000 volts DC. The scale markings on the meter are multiplied by 20 for the equivalent DC voltage.

With the switch in position 8, the meter indicates the relative amount of noise or audio voltage at the receiver output. The output of the receiver is connected to plug terminals 9 and 10, with terminal 10 leading to ground. For monitoring the receiver output, the audio voltage is applied to a speaker mounted in the tester. The speaker voltage is rectified and applied to the positive side of the meter. This becomes a convenient indication when making 20 db quieting tests, because the meter reads the relative amount of voltage, and 20 db represents a voltage ratio of 10 to 1. Meter readings for the different switch positions can be expected to vary from one model of receiver to another.

The recommended deflection for each switch position will be found in the instruction manual of the particular receiver being used. This information should be known when making tests in order to determine whether or not a particular reading can be regarded as normal.

The instruction manual also indicates the specific circuit which is monitored in each switch position. It is, therefore, essential for the serviceman to equip himself with the appropriate instruction manual whenever he uses the test set in conjunction with a receiver.

Transmitter Metering Circuit

In order to monitor transmitter circuits with the test set, the function switch (S1) is set to the METER position, S4 in its XMTR. position, and the meter reversing switch to (-). The circuit is shown in figure 4.

Positions 1, 2, 3, -4, 5 and 6 have the same circuitry and are used in the same way as they were in the receiver positions---to measure negative voltages. Position 1 is used with 450-mc transmitters to measure the amount of RF power in the transmission line (to the antenna). A crystal RF rectifier is incorporated in the transmitter, and the output voltage from this crystal is applied to the meter in position 1.

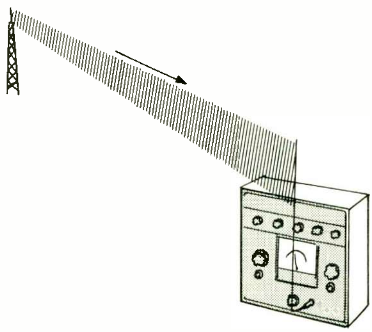
Position 2 is used (only in certain transmitters) to measure the amount of current in the oscillator stage. This makes it possible to adjust the oscillator for maximum activity, where this is necessary for the type of oscillator circuit employed. Positions 3, -4, 5 and 6 measure the grid current in the multiplier stages of the transmitter and they are used in tuning the plate circuits of preceding stages.

The P. A. position measures the plate current of the final amplifier stage of the transmitter. The plate current enters at terminal 8 of P1 and reaches the negative terminal of the meter, the positive side of the meter being returned to terminal 7, which is connected to the high-voltage circuit of the transmitter. Thus, the plate current of the power amplifier stage may be read in the P. A. position. A suitable shunt resistor is incorporated in the transmitter for proper meter indication. The multiplying factor for the meter reading is given in the instruction manual; it varies for transmitters of high and low power output.

Position 7 is used to measure the high voltage of the transmitter. The 20-megohm resistor provides a full-scale deflection of 1000 volts. Thus, the scale reading on the meter is multiplied by 20 to determine the high voltage.

Position 8 indicates the relay voltage which, in mobile applications, is the A supply to the filaments and relays. This voltage, made available at terminal 9 of the meter plug and at terminal 3 of the microphone receptacle, is applied to the meter through the 280 K multiplier resistor. An upward deflection indicates that the input voltage is positive, which means that the vehicle has the negative side of its primary voltage grounded. (If the positive battery terminal is grounded, the meter reverse switch must be used.)

In position 8, the meter becomes a voltmeter with a full-scale deflection of 15 volts. Thus the scale readings must be multiplied by .3 to determine the applied voltage. For example, a reading of 21 on the meter dial corresponds to 6.3 volts. The reading with the switch at position 8 always represents the voltage which is applied before the transmitter is operated. As soon as the transmitter is turned on, the test set indicates zero voltage with the switch at position 8. The line being measured is the "bottom" end of the relay, the control line for turning on the transmitter. In order to energize the transmit relay this line is grounded, either by the switch on the test set or by the one on the microphone.



The Motorola Test Sets May be Used to Measure the Field Strength of a Radiated Wave.

The microphone and audio output voltages are not measured by the P-8501 test set, but these voltages are available at terminal 10 of the meter plug and at the microphone receptacle, respectively. A microphone at the test set can thus be used to modulate the transmitter.

Signal Generator

Figure 5 shows the circuit of the signal generator. This unit consists of a crystal controlled oscillator followed by a multiplier. In addition to serving as a source of voltage at the IF frequencies of any Motorola receiver, the unit can also be used as an RF source for any receiver in the HI or LO bands. All that is required is the proper crystal.

By using the crystal from the transmitter, the combination of oscillator-multiplier provides an output at the channel frequency. Also, by using crystals of 440, 455 and 470 kc (assuming a 455 kc IF with a 15 kc deviation), it is possible to check the response of the discriminator in the receiver.

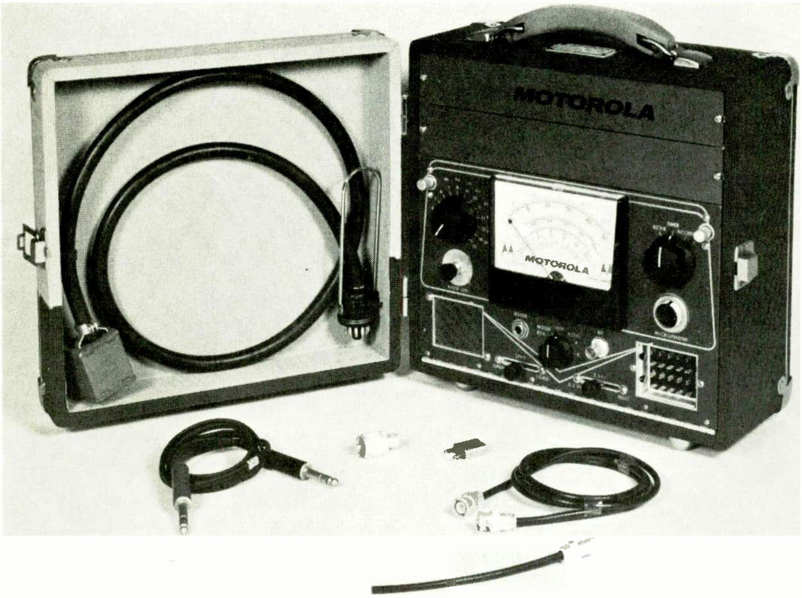
The series mode type of crystal used in some Motorola equipment will not operate properly in the test set. In some cases, in order to use the test set it will be necessary to secure a suitable fundamental mode crystal of the correct frequency.

The relatively high output of the test set, due to its multiplier stage, makes it suitable for alignment of both the RF and the IF sections of the receiver. For RF alignment, the output of the generator, available at the R.F. Out connector (D), is applied directly to the receiver antenna input by means of the cable which is supplied. The output is variable from maximum to zero by means of the attenuator (R9), which controls the screen voltage of both the oscillator and the multiplier.

Two tuning controls, ADJ. and OSC TUNE, are provided in the oscillator-multiplier section. At the low IF frequencies only the ADJ control is used---the other has no effect on either the frequency or the output. The function switch is placed in the GRID CURRENT position and the ADJ control is operated to obtain a maximum meter reading. This provides maximum output at the IF crystal frequency.

To obtain proper results at the higher frequencies, both controls must be used; the ADJ control becomes the means of placing the crystal on the correct frequency, and the OSC. TUNE is used to provide maximum output from the the multiplier. The output is best determined by monitoring the limiter in the receiver; the frequency should be "zeroed" to some discriminator known to be correctly tuned. For higher frequency operation, some small change of frequency may result when the ATTENUATOR or OSC. TUNE controls are varied. The frequency should be rechecked periodically to make sure the oscillator is always at the correct frequency.

The crystal heater obtains its operating voltage from the filament supply of the receiver, through terminal 8 of the meter plug. A resistor in this supply



The TU546 Test Set with Complete Accessories.

line is switched in or out of the circuit depending upon whether the receiver operates from a 6- or a 12-volt system.

The generator section of the test set operates from self-contained batteries, which supply 1.5 and 67.5 volts, respectively. The ON/OFF switch (S6) is used to connect these batteries to the generator circuits.

(For bench operation, an AC supply such as that shown in figure 6 may be built to save the batteries. The switch allows quick changes between AC and battery operation. The AC supply uses standard parts, all of which may be secured from most electronic supply houses. The components necessary for the construction of this AC supply can easily be mounted on a small chassis which may be installed inside the test set cabinet.)

Microammeter, RF Power and Dummy Load

To use the 0-50 microammeter alone, (1) the function switch is placed in the METER position, (2) position switch S4 is placed in the 0-50 position, and (3) the position switch is placed in the -4 position. The input to the meter is taken from 4 and 11 of the meter plug. The plug fits into an adapter which has connections to terminals 4 and 11, terminal 11 being the ground. This adapter terminates in a jack, which in turn fits into the Motorola dummy antenna, P-7208. The meter circuit, adapter, and dummy antenna load are shown in figure 7.

The TU546P Test Set Includes a Peaking Generator, Located on the Upper Panel.

Figure 7 shows how to determine the transmitter power output from the amount of current indicated on the meter. The power output in terms of current is also a function of the frequency; hence three curves are shown, one for each frequency range. For example; a reading of 30 microamperes in the 152-174 mc range corresponds to a power of 25 watts. Note, also, that the dummy load has a maximum continuous power rating of but 25 watts; for ratings higher than this, operation of the dummy must not exceed 5 seconds duration. If the resistors in the dummy load heat the rectifier crystal (also inside the dummy load), the current will change, resulting in an erroneous reading on the meter.[1]

Field Strength Meter

Figure 8 shows the circuitry of the test set when used as a field strength meter. All that is required is to set the function switch S1 in the FIELD STRENGTH position. This disables all switches and controls except the meter reversing switch. RF energy is introduced into the circuit through the PROBE input connector (C), and the rectifier converts it to an equivalent DC, which is then applied to the meter circuit.

No effort has been made to calibrate the readings on the meter in terms of uv/m (microvolts per meter), due to the several variables involved, which would make such calibration impractical. Moreover, a relative field strength reading is all that is desired by the average serviceman. Although there is no means of calibrating or determining the frequency of the signal being picked up by the meter, it is a means of indicating maximum output from the transmitter antenna. It is also very useful in loading the transmitter for maximum output.[2]

It takes .1 volt DC for full-scale deflection and .002 volt DC for a deflection of one dial division. The meter therefore cannot be used at any great distance from the trans-

1. See Test Methods, page 3-23.
2. See Test Methods, pages 1-5, 3-36, and 3-37.

mitter. By providing readings at various distances from the transmitting antenna, however, the field strength meter becomes a valuable instrument for detecting "dead spots."

The TU-546 Test Set

The TU-546 test set, besides performing all the functions of the P-8501 unit, has these additional advantages: No adapters are needed in order to measure the oscillator multipliers in 450-mc receivers; for checking microphone voltage, both the DC supply and the AC output can be measured; the set permits a zero-center discriminator scale reading; it incorporates a transistorized signal generator, having a range from 280 kc to 13 mc and there is provision in the test set for three separate crystals; the internal batteries may be checked by merely placing a switch in the correct position; a fully transistorized AC voltmeter is provided for measuring small AC voltages.

Provision is also made to use the test set with a "peaking generator," which can serve as an RF signal source for receivers up to 960 mc. This peaking generator is an accessory and may be included in the original test set or added afterwards.

Figure 9 is the basic schematic diagram of this test set. A cable shown at the left interconnects the test set with the receiver or transmitter, whichever is being tested. The function switch is normally placed at either RCVR or XMTR, whichever applies. The third position (ACCESS) of this switch disconnects the meter from the internal circuits. The meter movement is then available at the meter jack. In figure 9, the function switch terminals are indicated by the letters X(XMTR), R(RCVR), and A(ACCES).

The meter movement is not fused as in the P-8501 tester; instead, two silicon diodes in parallel with the movement perform the same function and make fuse replacement unnecessary in case of an overload. The meter is connected to the position switch (S1) through the meter reversing switch and the function switch.

Let us now inspect the circuitry of this test set at each position of Switch S1, for both the receiver and the transmitter. We will start with the receiver.

Receiver Measurements

With the set plugged into the receiver and the function switch in RCVR position, the position selector switch may be used to monitor many of the receiver circuits. In positions 1 through 6, the test set is capable of measuring grid currents in the various receiver stages. The negative side of the meter connects through terminals 1 through 6 of switch S1A to the various grid circuits which are to be measured. The positive side of the meter connects to ground in positions 1 through 6 (through the meter reversing switch, the function switch, and switch S1B). In series with this ground path we find a 17.5K resistor, the same as used in the 1-8501 tester. This ground lead completes its path to the receiver through terminal 11 of the plug.

Although position 4 has the same general circuitry as positions 1, 2, 3, and 6, this position is used to measure the secondary of the discriminator, which is a "zero" reading. To facilitate the meter deflection to both sides of zero, a special circuit is added to switch position 4 which places the normal position of the needle at the center of the meter scale. Special scale markings have a zero-center scale reading with graduations from zero in both directions.

Zero-center needle deflection in position 4 is obtained by means of a separate battery source and series connected resistors, which limit the current to 25 microamps (center-scale deflection). This circuit is shown to the right of the meter in figure 9. Switch S1D completes this circuit when the switch is in position 4, but the function switch must also be in its RCVR position. The 1.5-volt battery is now in series with a fixed resistor and a variable resistor, and the needle can be brought to exact center-scale deflection by adjusting the variable resistor. In any other position of the switch, the zero-center circuit is inoperative.

Positions 7 and 8 of the meter, (labeled PA and PO), are not normally used for receiver measurements except in the case of 450-mc receivers. With these receivers, the multiplier switch is placed in the MULT position, the meter now indicating the grid current for the circuits (the oscillator multipliers) terminating at plug terminals 7 and 8. By means of a spring-return arrangement, the switch will never be left in the MULT position except when making this specific measurement. As soon as the readings are completed the switch is returned to the 2 VAC position.

Position 11 provides for audio output measurements. The receiver audio terminates at plug connection 9, and with the function switch at RCVR, the audio is applied to the input of the AC voltmeter section. In parallel with this input (when the function switch is at RCVR), we find the speaker switch. This switch terminates the audio line into either a 3-ohm dummy load, a 3-ohm speaker, or a 27-ohm resistor in series with the speaker (which is effectively an "open" to the audio line).

The two stage amplifier (transistorized) terminates in a rectifier circuit in order to produce a reading on the meter. In position 11 the meter is connected across the ends of this rectifier circuit. With the AC Meter switch in the 2-volt position, a 2-volt input causes full-scale deflection. In the 0.2-V position, a 0.2-volt

AC input will cause full-scale deflection. Thus, the meter indicates the output voltage from the receiver.

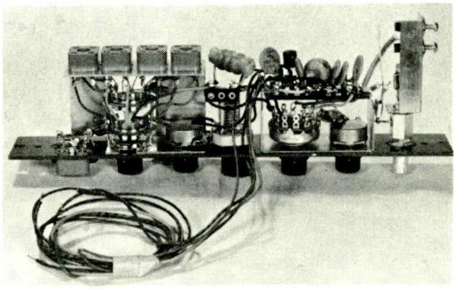
Transmitter Readings

When the test set is connected to the transmitter and the function switch placed in the XMTR position, a microphone may be plugged into the microphone receptacle, and either the mike switch or the switch on the test set may be used to place the transmitter in operation. The following readings may then be taken:

In positions 1 through 6 the meter indicates grid current, the same as for the receiver. Terminals 1 through 6 of the plug terminate at terminals 1 through 6 of switch S1A and, the circuit is completed through the meter to ground with only the 17.5K resistor in series.

Position 8, which is marked PO, is used only for determining the power output of 450-mc transmitters. A portion of the output power from the final tank is coupled through a rectifier to terminal 1 of the interconnecting plugs. Terminals 1 and 8 of switch S1A are interconnected through the function switch and the multiplier switch. So power output measurements of 450-mc transmitters can be made at either position. Position 8 is handier, however, since it is located next to position 7 (PA).

Position 7 is used to determine the plate current of the final stage.



Here We See the Transistorized Peaking Generator Which is a Part of the TU546P Test Set.

The circuit for this measurement is identical to that of the P-8501 test set. The meter and its series-connected 17.5K resistor are connected in parallel with the meter shunt resistor (in the plate supply lead to the final amplifier). The B supply lead and the plate side of the resistor are connected to plug terminals 7 and 8, respectively. The exact amount of plate current (the multiplication factor of the meter) is determined by the resistance of the shunt in the transmitter; the instruction manual must be consulted for the exact value of plate current for each transmitter.

In position 9 the meter indicates the plate supply voltage applied to the final stage of the transmitter. B plus is available at pin 7 of the plug connector and a 20-megohm resistor is connected in series with the meter to allow a 1000-volt DC full scale reading. This resistor is located between the B plus input at terminal 7 and terminal 9 of S1B. The circuit through the meter is completed to ground through terminal 9 of switch S1A.

In position 10 the meter indicates the A supply voltage applied to the relays. If the relays operate from a battery supply, this reading represents the battery voltage. Terminal 10 of S1A is grounded and the positive side of the meter connects to terminal 10 of S1B. By means of 300K series-connected resistor at this terminal, the meter will read 15 volts, full scale, useful for both 6- and 12-volt systems. This A voltage is available at terminal 9 of the plug connector but the circuit to the meter is completed only when the function switch is in the XMTR position (dotted lines).

In position 11 the meter indicates the audio output from the microphone. The audio component of the mike voltage (available at terminal 1 of the mike connector) is applied to the input of the amplifier and the meter is connected across the output of the amplifier, the circuit being the same as for the audio output of the receiver. With the function switch in the XMTR position, however, the speaker switch is no longer in parallel with the amplifier input. The microphone may be that of the transmitter or it may be one plugged into the test set. In either case, normal voice modulation causes a reading of about 0.25 volt on the meter, assuming a higher voltage output type of microphone. For lower voltage microphones the reading will average 0.18 volt. For this test the transmitter must be placed in operation or there will be no microphone DC supply voltage.

Position 12 of the switch is used to measure the microphone DC supply. The path between terminal 10 of the plug connector and terminal 1 of the microphone receptacle is completed through a 600 K resistor to terminal 12 of S1A, through the meter, and to ground at terminal 12 of switch S1B. The 600 K resistor is used for a full-scale reading of 30 volts, which is adequate for the microphone supply.

Position 13 is used to obtain an immediate check on the condition of the internal battery of the test set.

Position 14 is used to measure the relative amount of RF output of the internal crystal oscillator. A small coupling capacitor feeds the oscillator output to a voltage doubling rectifier circuit and results in a relative reading on the meter. Position 14 is also used when the test set operates as a field strength meter. The output of the pick-up antenna is connected to the RF connector. With the switch in position 14, the meter indicates the RF level.

The Crystal Oscillator

The transistorized crystal-controlled oscillator, shown at the lower right of figure 9, operates at any frequency between 280 kc and 13 mc. The principal purpose of this oscillator section is to provide a signal at the various IF frequencies for receiver alignment. Three internal crystal sockets are provided, selection being made by means of the switch on the front panel. The oscillator uses "AQL" type crystals for frequencies up to 800 kc and "ANL" type crystals above 800 kc. These are both anti-resonant crystals (appearing as a parallel tuned circuit to the oscillator).

Position 14 is used for automatically monitoring the output of the oscillator, giving a relative indication of crystal activity. This is particularly useful in checking the activity of unknown crystals. Due to the differences of frequency ranges and cuts of crystals, however, and due to the limited supply voltage to the oscillator, the failure of a crystal to operate is no proof that the crystal is defective.

Peaking Generator

The transistorized RF peaking generator provides a high order of harmonics of the fundamental 6-10 mc crystal oscillator frequency, and serves as a signal source for the low band (25-54 mc), the high band (144-174 mc), the 450-470 mc band and the 890-960 mc band. If not originally included with the test set, this generator may be added later as an accessory item.

The peaking generator makes use of an "AUL," anti-resonant type of crystal. In some instances the crystal from the transmitter oscillator will operate satisfactorily; if not, crystals may be purchased at low cost for any channel of operation. A frequency adjustment is provided for placing the generator on exact channel frequency, and an output attenuator provides the desired amount of RF signal for the receiver.

STUDENT NOTES

STUDENT NOTES

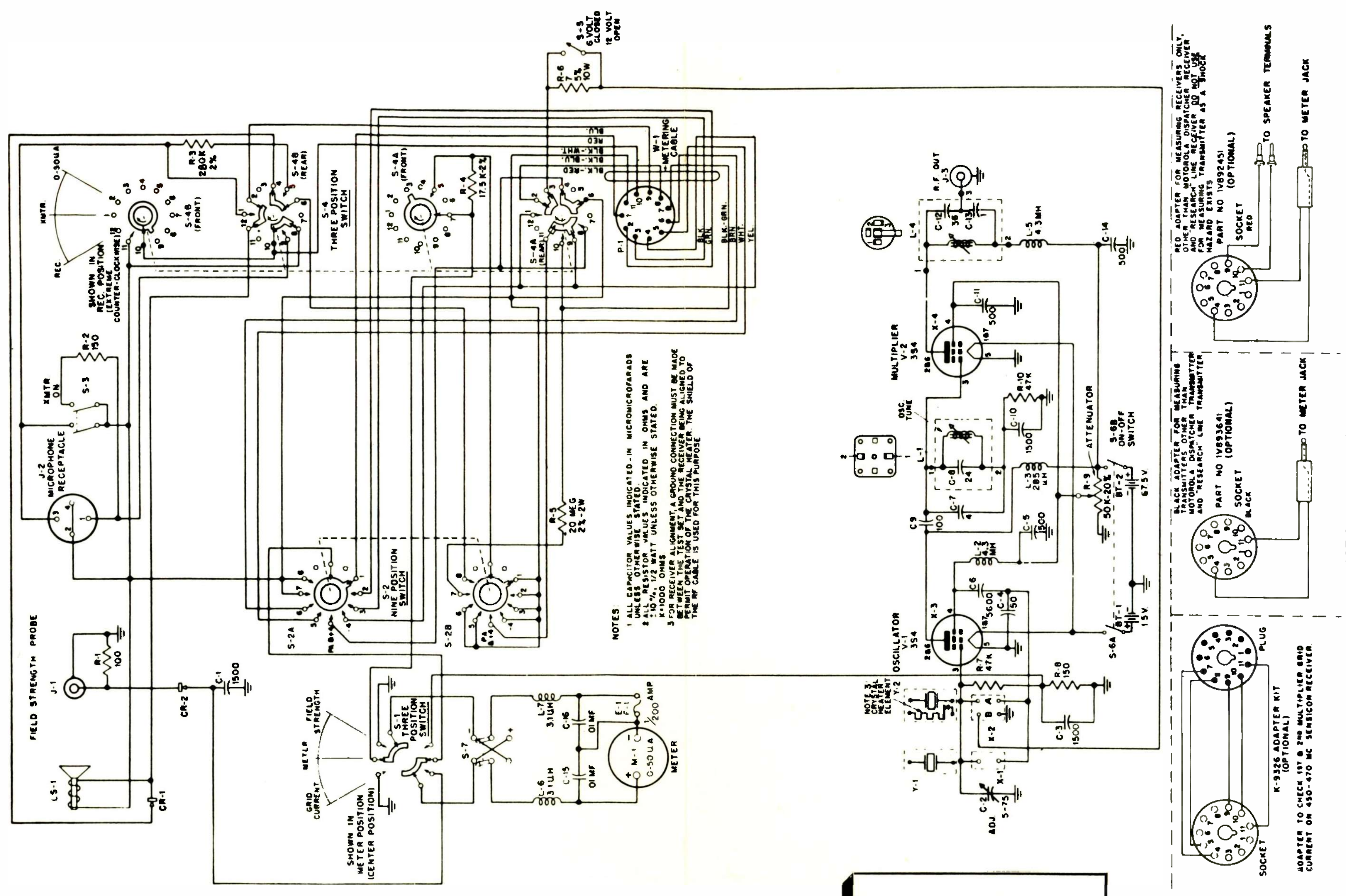


FIGURE 2

FIGURE 1
is on the
back of this page

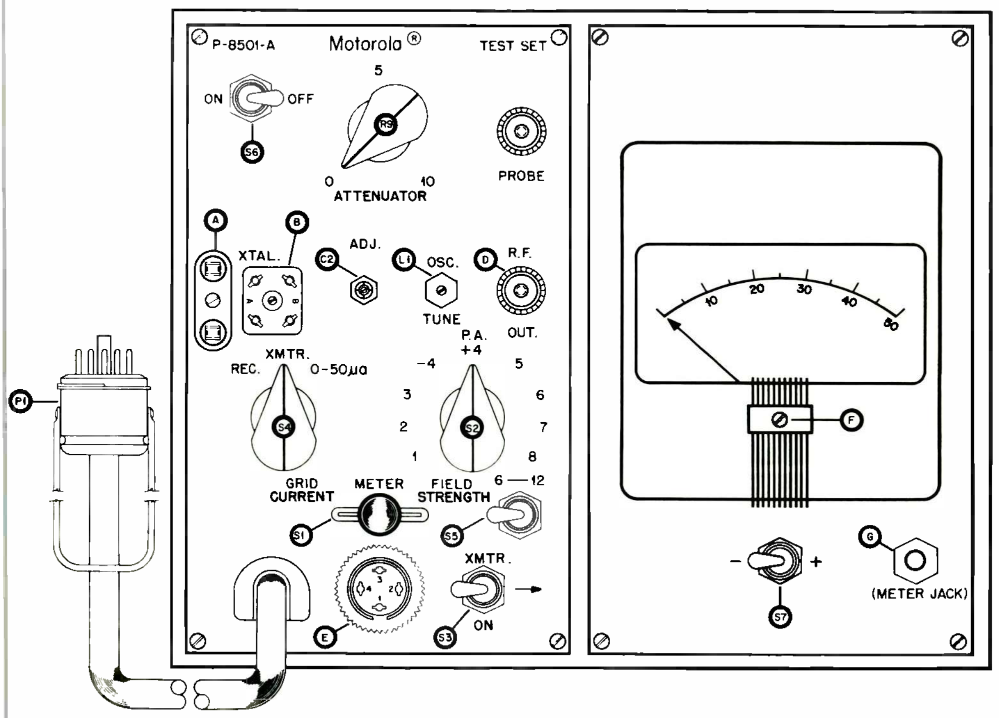
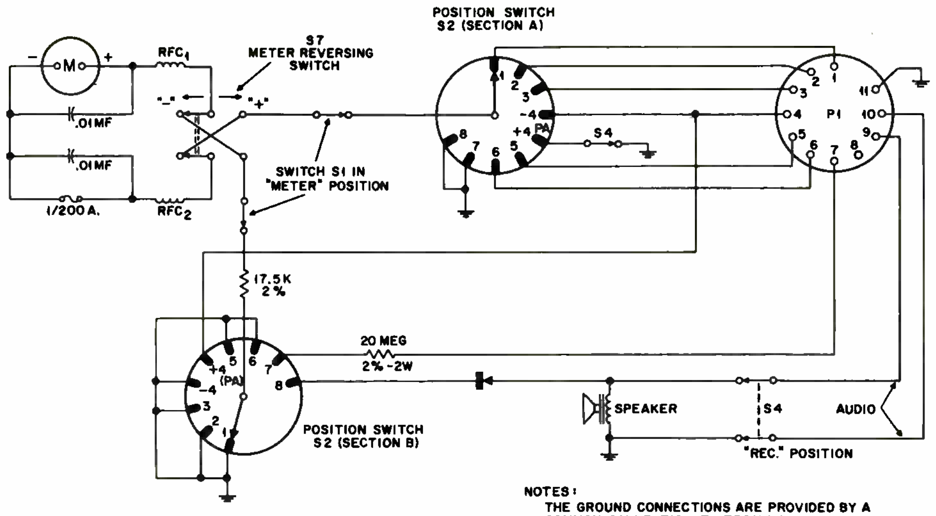


FIGURE 1

STUDENT NOTES

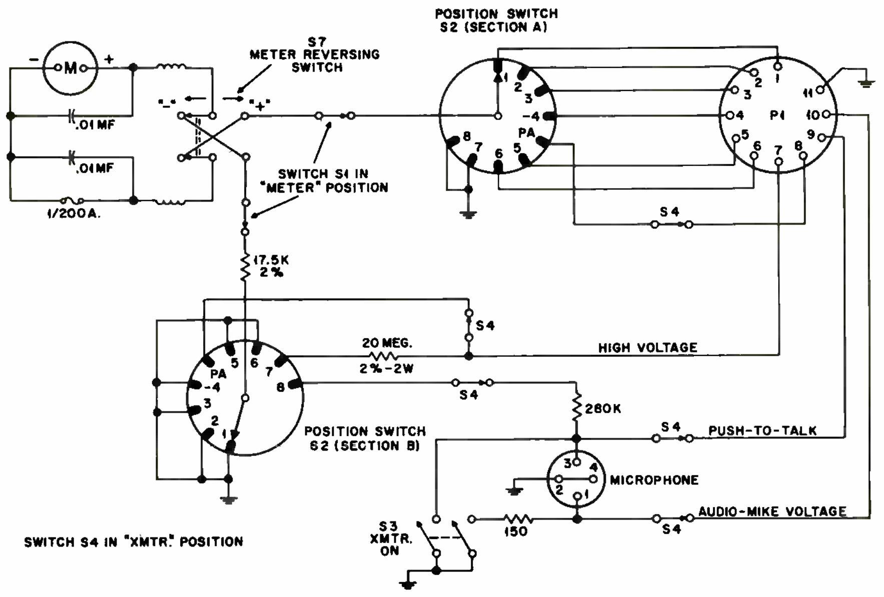
STUDENT NOTES

STUDENT NOTES



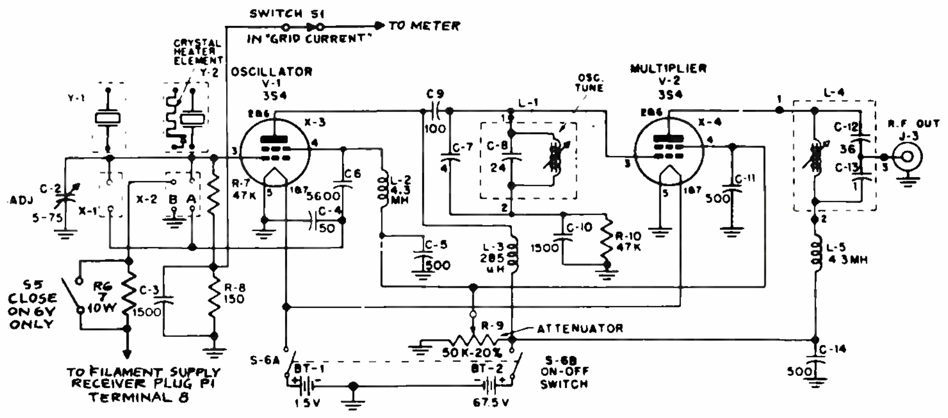
NOTES:
THE GROUND CONNECTIONS ARE PROVIDED BY A COMMON CONNECTION TO TERMINAL 11 OF P1, WHICH IS GROUNDED THROUGH THE RECEIVER CHASSIS.
SWITCH S4 IN "REC." POSITION.

P-8501-B TEST SET--RECEIVER METERING CIRCUIT
FIGURE 3

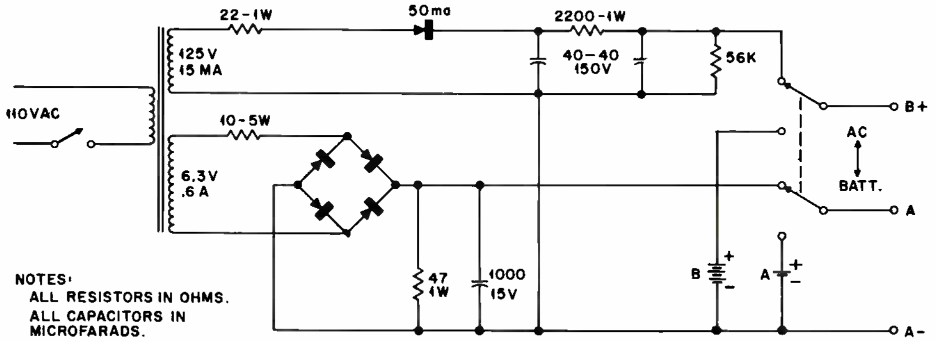


SWITCH S4 IN "XMTR." POSITION

P-8501-B TEST SET--SIMPLIFIED DIAGRAM OF TRANSMITTER METERING CIRCUIT
FIGURE 4



TEST OSCILLATOR OF
MOTOROLA P-8501-B
TEST SET
FIGURE 5



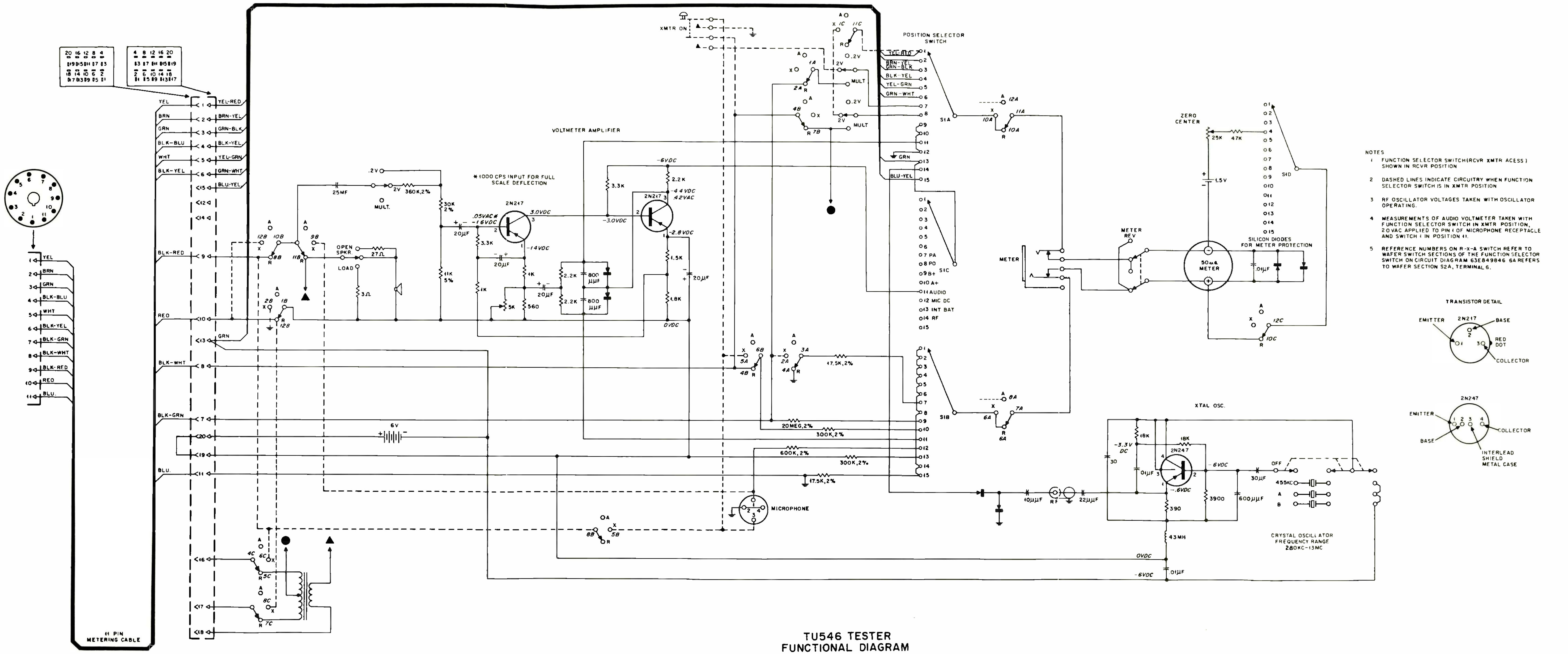
NOTES:
ALL RESISTORS IN OHMS.
ALL CAPACITORS IN MICROFARADS.

AC POWER SUPPLY
FIGURE 6

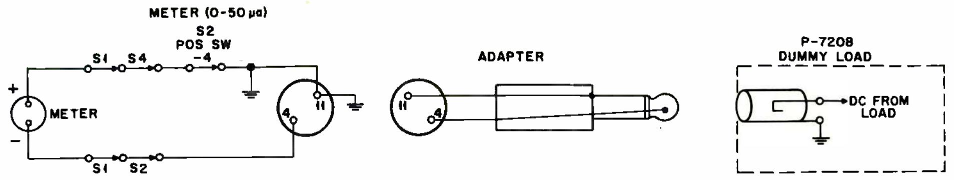
STUDENT NOTES

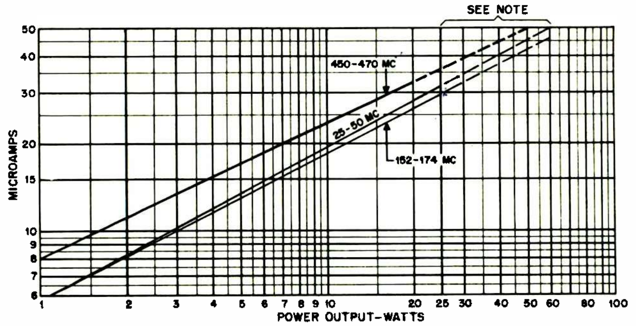
STUDENT NOTES

STUDENT NOTES



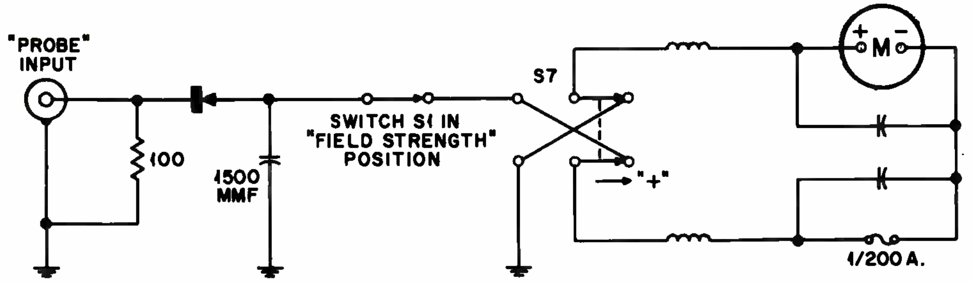
TU546 TESTER
FUNCTIONAL DIAGRAM
FIGURE 9





NOTE:
LOAD RATED AT 25 WATTS CONTINUOUS DUTY AND
UP TO 60 WATTS FOR SHORT PERIODS (5 SECS. MAX.).

FIGURE 7



NOTES:
SWITCH S1 IN "FIELD STRENGTH" POSITION
METER REVERSING SWITCH S7 IN "+" POSITION

"FIELD STRENGTH" CIRCUIT OF P-8501-B MOTOROLA TEST SET
FIGURE 8

national

MOTOROLA

RADIO COMMUNICATIONS

service

A TWO-WAY RADIO COMMUNICATIONS TRAINING PROGRAM

LESSON MA-2
SPECIAL SYSTEMS

Selective Signaling Equipment

MOTOROLA TRAINING INSTITUTE

A TWO-WAY RADIO COMMUNICATIONS TRAINING PROGRAM

LESSON MA-2
SPECIAL SYSTEMS

Selective Signaling Equipment

—one of a series of lessons on two-way FM communications—

MOTOROLA TRAINING INSTITUTE
4501 W. AUGUSTA BLVD., CHICAGO 51, ILLINOIS
APPROVED BY THE STATE OF ILLINOIS
DEPT. OF REGISTRATION AND EDUCATION

PREFACE

This is one lesson of a complete Motorola Home-Study Course which presents to the Service Technician both the principles of operation and the maintenance of two-way FM radio systems. The program covers mobile, portable and base station equipment, including the latest transistorized units.

SELECTIVE SIGNALING EQUIPMENT

LESSON MA-2

TABLE OF CONTENTS

NOTICE

Diagrams and figures referenced in text are "fold-outs" in back of each lesson, for use while studying. The Examinations are also there.

Providing prompt customer service, be it orange juice or rug cleaning, is essential in this competitive age. Thousands of customer service firms are utilizing two-way mobile radio to increase the speed and efficiency of their operations.

SELECTIVE SIGNALING EQUIPMENT

Lesson MA-2

Introduction

In the preceding lesson we discussed the need for a two-way communications system which would provide a certain degree of "privacy" when a channel is shared with others in the same area. We found a solution in the Private Line tone coding system. In this system, receivers will not respond to signals on the channel frequency unless the signal includes the proper coding tone to keep the receiver squelch open.

Selective calling equipment insures privacy between stations operating within one system. Motorola's QUIK-CALL system does just that. Either individual stations or combinations of stations may be selected to receive a particular transmission without disturbing other receivers in the same system. This selection is operative only from the base station, not from the mobile units. So long as a receiver is not "called" by the base transmitter, it also will be unresponsive to transmission from other systems using the same channel. This affords a certain degree of "private" operation, for the receiver responds only to those messages meant for it; the operator does not have to listen to a lot of messages which do not concern him.

In operation, the audio circuit is broken before the signals reach the speaker, so that none of the undesired messages will be reproduced. This audio circuit is completed (by the closing of a relay) only when certain coding tones are received. Four tones are used by the QUIK-CALL system, in order to provide a great number of combinations for alerting the different receivers. Since two of the coding tones may be common to several receivers, this arrangement provides considerable flexibility for group calling.

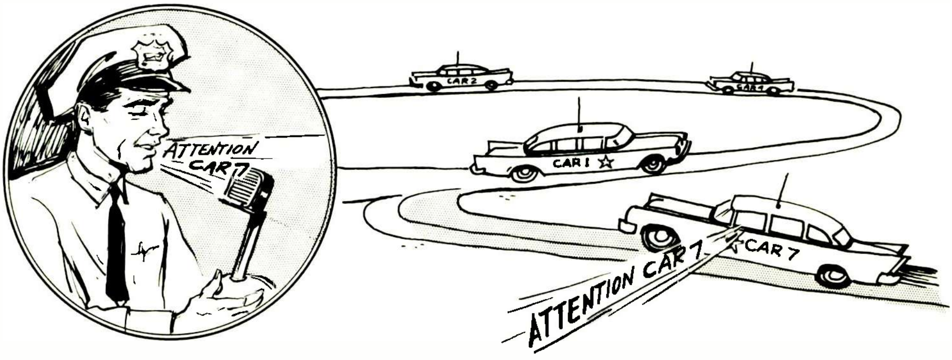
Transmission of the coding tones is automatic. The operator merely selects the tones corresponding to the receiver he wishes to call and then depresses a "code start" button. This activates several relays and timing circuits, which send out the proper alerting tones. The first two tones are transmitted during the first 3/4 second; after a short "silent" interval, the second group of two tones is sent.

All four coding tones will have been transmitted within two seconds from the time the operator depresses the start button. A neon lamp on the control panel tells the operator that the tones are being transmitted. As soon as the coding tones are completed this lamp goes out, which means that the operator may now transmit his message without interfering with the coding signals.

Figure 1A shows a block diagram of the QUIK-CALL equipment used in connection with the transmitter. Twelve tone-oscillators are in constant operation, each oscillator generating a very stable audio signal. For convenience, each tone is identified by a number or letter. In low-frequency tone systems the first 10 tones are identified by the numbers 1 through 0, and the letters A and B designate the two final tones. (High-frequency tone systems have letter designations from C to P, I and O being omitted.)

and 5 and 7 of the second row. He then pushes the "code start" button momentarily and the signal tones are automatically transmitted. When they are completed, the lamp goes out. The operator may now talk to the operator at the selected receiver.

From the selector, figure 1A, the selected tones are next applied to the timer. The first group of tones selected on the upper row of buttons are transmitted for 0.75 second. (The transmission is controlled by a tube, several relays, and associated circuitry.) After 0.75 second, the transmission of



Quik-Call Radio Provides Selectivity Within a System: One Car may be Called Separately--the Remaining Vehicles in the System are Silent.

The output of the oscillators is fed to the selector box where we find two rows of buttons, the 12 buttons of each row being labeled from 1 through B for low-frequency tones. If the operator wishes to call a receiver having code tones of 1 and 3 for the first tone pulse and tones 5 and 7 for the second code pulse, he depresses buttons 1 and 3 of the first row of buttons

the first group of tones is stopped and there is an interval of about 0.2 second before the second tone pulse starts. This interval is also controlled by a timing circuit. The second group of tones is sent in the next pulse, which also lasts for about 0.75 second. With the completion of this pulse, the QUIK-CALL equipment has performed its assigned function.

Another button at the selector box enables the operator to make a "group call" to several receivers having common code tones. The selection of these tones is made from the lower row of buttons and the operator then depresses the "group-test" button for 4 seconds. All receivers having the tones selected for this group call are thus alerted.

The tones, selected for either QUIK-CALL or group call, pass through an amplifier section before reaching the transmitter. The tone level at the oscillator output is not strong enough to properly modulate the transmitter, so an amplifier becomes necessary. The power supply shown in figure 1A is used both by the tone oscillators and by the amplifier.

At the receiver, the speaker remains disconnected from the output until the proper coding tones have been received. These tones activate a control relay which closes the audio path to the speaker. The block diagram of figure 1B testifies to the simplicity of the system. So long as the operator leaves his microphone (or handset) "on the hook," the receiver will be in QUIK-CALL condition. The relay remains deenergized until the correctly coded signals are received. When this happens the relay connects the receiver output to the speaker. When the operator removes the microphone, however, the speaker is connected directly to the receiver output and the receiver is no longer controlled by the QUIK-CALL circuitry. We shall study this arrangement in detail later.

Pulse Control Circuits

Figure 2 shows the basic method for controlling the transmission of the first group of QUIK-CALL tones. The tones required for the first pulse are selected by depressing the corresponding buttons (switches) in the top row of buttons on the control panel. These tones are transferred to the audio amplifier, but first the contacts of relays K101 and K-1 must be closed. To close relay K101 (located on the selector panel chassis), a sequence of events must take place. First, the "code start" switch is depressed; this charges capacitor C4, which sets the first pulse timer in operation.

As a result, relay K1 (in the cathode circuit of the timer tube V1A) is operated and its contacts are closed. This in turn (1) completes the tone path to the audio amplifier, and (2) completes the path which allows relay K3 to energize.

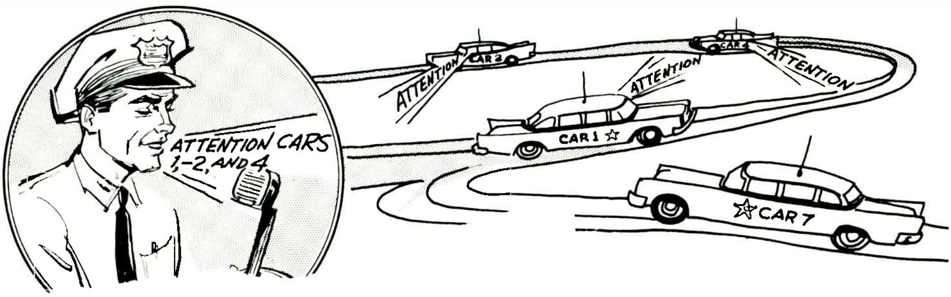
Relay K3 serves three fundamental purposes in figure 2. First, it turns "on" the transmitter by causing the transmit-receive relay to close. Second, it closes a timing circuit which keeps relay K1 energized for approximately 0.75 second. Third, it closes the path for the operation of relay K101. With relay K1 locked for 0.75 second, relays K3 and K101 will also remain energized during this time. Relay K101 has completed the path for the two tones, which are now applied to the audio amplifier. The tones at the amplifier output are applied to the transmitter modulator.

Relay K1 releases after 0.75 second, but another circuit holds relay K3 until the second tone pulse is started. (This keeps the transmitter on the air.) Relay K1 has released, however, and the tones no longer reach the modulator. Until the second pulse starts, then, there is a short period with no modulation.

complete the circuit, keeping K3 closed, and K3 in turn keeps relay K101 energized during the second pulse. The tones selected by the second row of buttons are now transferred to the input of the audio amplifier through the contacts of relays K101 and K2. The transmission of this second pulse lasts for the 0.75 second that relay K2 is held by its timing circuit.

The Console

Figure 4 shows the complete



An Important Feature of Quik-Call is Group Calling: a Predetermined Group of Vehicles may be Called Simultaneously.

The operation of the second pulse is illustrated in figure 3. Capacitor C2B has charged during the time that relay K1 was operated. When the relay releases, the charged capacitor is connected into the grid circuit of the second timing tube, V1B. The tube conducts and K2 closes, being held closed for approximately 0.75 second by means of a timing circuit. The contacts of relay K2

circuit of the QUIK-CALL console. Located near the operator at the base station, this console contains all the components necessary to generate, select, and time the QUIK-CALL signals used in this system.

The console is made up of two basic sections, (1) the selector panel and (2) the power supply and timer chassis. On the selector panel there are two rows of buttons from which the operator selects the various coding signals, a "code start" button which is depressed to start a coding signal, a "group test" button for group calls, a "release" button to release the depressed buttons, an "auto-rel." button which provides automatic release of the buttons after a completed code transmission, an indicator lamp which lights during the transmission of coding signals, and a meter which monitors the level of the tones being sent to the transmitter.

The power supply and timer chassis includes (1) a power supply, (2) a 12-tone oscillator deck (3) the timer circuits, and (4) an audio amplifier section. We shall start our detailed analysis of the QUIK-CALL equipment with the power supply.

The Power Supply

The power supply furnishes four output voltages: 250 VDC, 210 VDC, 8 VDC and 6.3 VAC. These voltages are obtained from two secondary windings. The high-voltage winding has a full-wave bridge selenium rectifier section, with an output of approximately 250 volts (at the filter input). This is used for the high DC supply (designated B++). The low DC supply (210 volts) is provided at the output of the filter section. The 6.3 VAC filament winding is also used to obtain the 8 VDC output. A single rectifier and a filter section produce the positive 8 volts, which is used as a biasing voltage at the cathodes of the tubes in the timing circuits.

Tone Oscillator Deck

Only one tone oscillator is shown in figure 4; the others are identical. The oscillator uses a 5963 twin triode, a ruggedized version of the 12AU7 tube. The oscillator, which is similar to the tone oscillator discussed in the preceding lesson, operates as a multivibrator. Section A of the tube is the basic oscillator, with section B acting as a feedback amplifier and phase inverter. The vibrasender is in parallel with the feedback voltage from the plate of tube section B to the grid of the oscillator; only that frequency which corresponds to the natural vibrating frequency of the reed can produce oscillation. The vibrasender has a very high effective Q and it maintains a high degree of frequency stability.

Capacitor C202 between the two plates provides negative feedback, which reduces the harmonic content and makes the output waveform nearly sinusoidal. The oscillator output is taken from across the plate circuit of section B, and an isolating resistor and capacitor are connected in series with a potentiometer, the output of the oscillator being controlled by the adjustment of the potentiometer. Each oscillator has a separate output voltage control. A Master

Tone Control, located near the individual tone output adjustments, determines the voltage applied to the amplifier, thus regulating the amount of modulation voltage to the transmitter. The output of the tone oscillators is terminated at the switches on the control panel. Each tone is connected to its two corresponding switches, one each in the top and bottom rows.

The Complete Tone Path

The first two tones of a 4-tone QUIK-CALL transmission are selected on the upper row of buttons, switch S105 in figure 4. This switch is mechanically designed so that only two buttons may be depressed at any one time. The tone with the lower number is applied to contact 5 of relay K101, and the second tone to contact 7.

When relay K101 is energized, the tones are combined (relay contacts 6 and 8 are tied together) and reach contact 12 of relay K1 in the timer circuit. When relay K1 is operated, the tones are applied through contact 11 of the relay to the Master Tone Control, R43. Resistor R43 applies all or some portion of the tone voltage to the audio amplifier, V2.

The output of the amplifier is available at terminals 7, 8, 9 and 10 of terminal board TB1. The connection to terminal 7 is completed only when relay K3 is operated. Terminals 7 and 8 supply a small output voltage with an impedance of 125 ohms. The same voltage and impedance is present at terminals 9 and 10, but the voltage at terminals 9 and 10 is connected directly to the output transformer and does not depend upon the contacts of relay K3. Output terminals 7 and 10 are used for a larger output voltage, at an impedance of 500 ohms, when a jumper is connected between terminals 8 and 9.

A meter on the control panel is used to monitor the level of the tones being sent to the transmitter. Calibrated in decibels, this meter is connected across the full output of the amplifier and indicates the relative amplitude of the tones.

The path for the tones selected from the lower row of buttons (S106) for the second pulse is similar to the path for the first pulse except that they reach the amplifier by passing through contacts 1, 2, 3 and 4 of relay K101 and contacts 6 and 7 of K2.

The Audio Amplifier

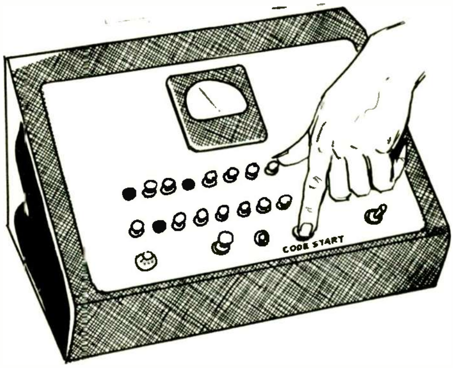
The audio amplifier provides the necessary amplification for the audio tones to give them sufficient amplitude to modulate the transmitter. A single 5963 type tube is used for both stages of the amplifier.

The left-hand section of the tube is the first stage. Its cathode bias resistor is unbypassed in order to provide negative feedback, thereby improving the frequency response. Resistor R26 is the plate load, with the output capacitively coupled (C8) to the grid of the right-hand section. This section also uses an unbypassed cathode bias resistor. Still further improvement of the frequency response is realized by means of the feedback capacitors (C6 and C7) between the plates of the two triode sections.

The transformer has a split secondary, each winding an impedance of 125 ohms. When these windings are connected in series (by placing a jumper between terminals 8 and 9 at the terminal board), the total secondary impedance is 500 ohms. For applications requiring output voltages between 0.5 and 1.5 volts, connections are made to terminals 7 and 8 of the terminal board; for an output of from 1 to 3 volts, terminals 7 and 10 are used. Where less than 0.5 volt is desired, a voltage divider consisting of resistors in series and having a total resistance of 500 ohms is connected between terminals 7 and 10, with the output taken from the appropriate point on the divider. When using any of these connections, it is necessary to install a jumper between terminals 8 and 9.

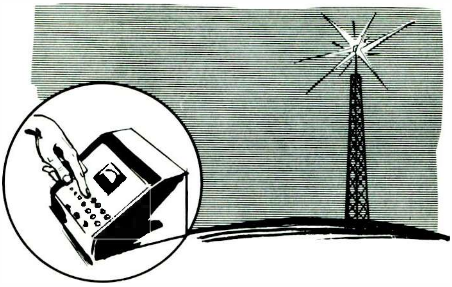
First Tone Pulse

To transmit a QUIK-CALL signal, the operator first depresses four buttons, two in the upper row and two in the bottom row. He then pushes the "code start" button, holding it down until the red indicator lamp goes on, which happens in less than one second. The operator may now release the "code start" button. The transmission of the proper QUIK-CALL tones will be performed automatically. Let us now analyze the operation of the equipment during the transmission of the first pulse. In order to make it easy to follow this first tone pulse operation, the circuit is printed in red in figure 4.



Quik-Call Code Tones are Automatically Operated, Timed and Transmitted as Soon as the Operator Depresses the Code Start Button.

We have already traced the path of the tones selected by the buttons in the upper row (switch S105). For these tones to reach the modulator, it is necessary to energize relay K1, which in turn operates relays K101 and K3. When the "code start" button is depressed, the 250 volt (B++) supply is applied to the grid of timer tube V1A, making that tube conduct heavily. Here is how this is accomplished. Terminal 2 of the start switch (S101) is connected to B++. This voltage is applied through switch contacts 1 and 2 to the grid of circuit of V1A. Capacitor C4 is in series with the grid resistor R8, but the full supply voltage is impressed across the resistor the instant the switch contacts engage.



Quik-Call Allows for Remote Control by Radio. Here a Distant Tower Light has been Turned On.

The cathode return path is through the coil of relay K1 to the positive side of the 8-volt bias supply. This voltage does not initially bias the tube to cut-off but, without the positive pulse at the grid, the cathode current is too small to energize the relay. As soon as the positive pulse is applied to the tube grid, however, the tube conducts heavily and the relay energizes. As we know (from the simplified sketch of figure 2), this controls the transmission of the first two tone pulses.

The holding of relay K1 for 0.75 second is accomplished in connection with the operation of relay K3. When relay K1 operates, its contacts 4 and 5 close, applying 250 volts to the coil of relay K3. (Resistor R20 limits the current in the relay coil to the proper amount.) Before relay K3 is energized, its contacts 9 and 10 are closed, completing a path for charging capacitor C2A. The complete circuit is through resistor R21 and contacts 8 and 9 of relay K2. Thus, before relay K3 energizes, capacitor C2A has been charged to 250 volts.

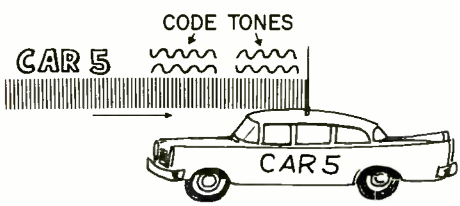
When K3 is operated by the action of relay K1, capacitor C2A is connected into the grid circuit of V1A through relay contacts 10 and 11. This positive charge maintains V1A conductive for approximately 0.75 second, and controls the timing of the first pulse. The pulse duration can be changed by using one of the alternate resistor connections (R7-R10) in the grid circuit of V1A. A large resistance produces a longer pulse. A small resistance permits a faster discharge of C2A, and hence a shorter pulse results.

Relay K1 has several other functions besides operating relay K3. The closing of contacts 11 and 12 completes the path for the tones to the grid of the amplifier. Contacts 6 and 7 are used in connection with remote operation. (This ground circuit discontinues the operation of the equipment from the remote position.) Contacts 1, 2, 3, 8, 9 and 10 are for the control of the second pulse and will be discussed shortly.

When relay K3 energizes, several other functions are provided besides the holding of relay K1. The closing of contacts 1 and 2 applies 250 volts (1) to the red indicator lamp on the selector panel and (2) through contacts 3 and 4 of the code start switch, S101, to the coil of relay K101. Relay K101 then closes, applying the audio tones to the amplifier. In order for relay K101 to become energized, however, the code start button must be held down (for a fraction of a second) until the indicator lamp lights, indicating that B++ has been applied to K101.

Three pairs of normally open contacts on relay K3, connected to terminals 1 through 6 of the terminal board, are used respectively (1) to operate the transmit relay of the transmitter, (2) to mute the microphone during code tone transmission, and (3) to perform any other similar function. When contacts 12 and 13 of the relay close, they complete the audio output circuit from the amplifier to the modulator. Contacts 14 and 15 are used to apply 6.3 volts AC to remote equipment for certain control purposes.

So much for the operation of the first tone pulse. The tones selected in the top row of buttons are sent to the amplifier, reach the modulator stage of the transmitter, are placed "on the air," and finally reach the receiver. This pulse is transmitted for a period of 0.75 second, during which time relays K1, K3 and K101 remain energized.



Quik-Call Operation Depends upon Four Coding Tones Sent at the Beginning of the Transmission.

Pulse Spacing

For the proper operation of QUIK-CALL equipment, it is essential that the second set of pulse tones be delayed for a short period of time, 0.2 second being sufficient. Unless this is done, receivers having the same coding tones, but in a different order, will respond to calls not meant for them. This condition arises as a result of the continued vibration of the vibrasponder reeds in the receiving equipment for a short time after the tone transmission has been discontinued. It is thus necessary to insert a short interval of no modulation after the first pulse, to permit the reeds in the vibrasponders to stop vibrating. After 0.2 second the reeds will have damped to such an extent that contact will no longer be made.

The required spacing is accomplished by the discharge of two capacitors, C3 and C2B, into the grid circuit of V1B. During the first pulse (while relay K1 is energized), capacitor C3 is charged to 250 volts, with its "right-hand" side (as shown in figure 4) positive with respect to ground. (The left-hand side of the capacitor is grounded through relay contacts 9 and 10.) Capacitor C2B is also charged to 250 volts, through relay contacts 2 and 3.

As soon as relay K1 releases, these two capacitors are connected so that they discharge through R16, the grid resistor of the second pulse timer, V1B. The positive side of C2B is connected to the grid through contacts 1 and 2, while the negative side of C3 is connected to the grid by the action of contacts 8, 9 and 10 of the relay. The negative charge on C3 is applied to the grid directly, but the positive charge (on C2B) is "delayed" by the series connected resistor R14, which makes the time constant of this circuit much longer than that of C3.

Thus, the grid of V1B first becomes negative, remaining so for a short period of time. As capacitor C3 discharges quickly, the grid soon becomes less negative. At the same time, capacitor C2B discharges through R14 and R16, forcing the grid to swing positive. Within 0.2 second, the grid reaches the point where V1B conducts, operating relay K2 in its cathode circuit.

During the brief interval between the end of the first pulse and the beginning of the second pulse, it is necessary for relays K3 and K101 to remain energized. Relay K101 will remain energized as long as relay K3 is energized. Relay K3 supplies 250 volts to terminal 13 of relay K101, and with contacts 12 and 13 closed, this 250 volts is applied to its coil, thereby locking the relay. The only way in which this relay will now open is to remove the 250-volt supply by releasing relay K3. Relay K3 is held closed between pulses by the charge that has accumulated on capacitor C5. (When relay K1 is energized, C5 charges to 250 volts through contacts 4 and 5.) When relay K1 releases, this capacitor discharges through the coil of K3, keeping this relay energized.

Second Tone Pulse

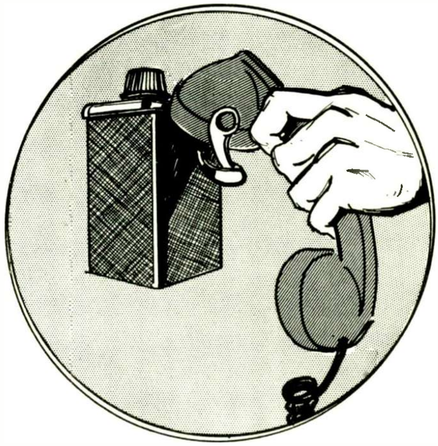
As soon as the second pulse begins, relay K3 is operated through the contacts of relay K2. We have already seen the basic operation of relay K2 (figure 3). This relay performs several functions. For one thing, it causes K3 to operate. This is accomplished by means of contacts 9 and 10 (of K2) which apply 250 volts to the coil of K3. Contacts 6 and 7 of K2 close, completing the path for the tones to the audio amplifier. This path is also completed by closed contacts of relay K101 (but this relay, we know, is being held closed by K3). Contacts 11 and 12 of K2 close, completing the grid return to ground through resistor R11. This smaller grid resistance establishes the correct timing circuit for the grid of V1B. Before relay K2 can release, capacitor C2B must discharge. The path is now through R11, and this time constant is correct for the second pulse. In the meantime, contacts 2 and 3 of K2 also close, charging capacitor C1B to 250 volts. We shall see the purpose for this later.

After 0.75 second, C2B no longer holds the grid of V1B sufficiently positive for its cathode current to operate relay K2; as a result, K2 releases. When K2 releases, K3 and K101 also release. The transmission of the second set of code tones is now completed. The red indicator lamp goes out, the meter on the selector panel reads zero, and the transmit-receive relay (in the two-way equipment) also releases, placing the equipment in standby (receive) condition. If the operator wishes to send a message, however, he may use the mike button (or foot switch) to keep the transmitter on the air after the tone transmission is completed.

Selector Button Release

Provision is made for the operator to release any buttons that may be depressed, at any time. An "AUTO. REL." (automatic release) switch also provides for releasing the buttons automatically at the termination of the second pulse.

The manual "RELEASE" switch, S102, normally connects the 250-volt supply line to capacitor C101 and the capacitor is usually fully charged. As soon as this "release" button is depressed, however, the capacitor is connected to the coil of the "button release solenoid" (L101). The solenoid immediately releases both rows of selector buttons.

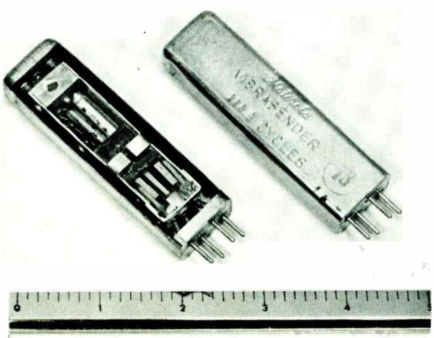


Lifting the Handset from the Hang-Up Box Stops Quik-Call Operation and the Receiver Operates in a Normal Manner.

Automatic release is accomplished by capacitor C1B through contacts 1 and 2 of relay K2. When this relay is energized during the second pulse, the capacitor is charged to 250 volts through contacts 2 and 3. When the relay releases at the end of the second pulse transmission, this charged capacitor is connected (through contacts 1 and 2) to the "button release solenoid." The functioning of this circuit requires switch S104 to be in its automatic position. Also, relay K101 must be energized, for the path is through its contacts 10 and 11. (It is normal for this relay to remain energized for a short time after relay K2 releases.) If the switch is not in the "AUTO. REL." position, the manual "RELEASE" button must be used.

Group-Call

Besides alerting a single station within the system by means of the 4-tone, 2-pulse system, it is also possible to make a call simultaneously to a group of stations within the system. Two tones are necessary for group-call, and they are selected on the bottom row of buttons. Instead of pushing the code start button, the "group-test" button is now depressed. The timing of this transmission is now no longer automatic. Instead, the timing is up to the operator, and for this operation he must keep the button down for approximately four seconds in order to properly alert the desired stations.



Quik-Call Code Tones are Controlled by Vibrasenders, the Same as in Private Line Systems.

When the "GROUP-TEST" switch (S103) is closed, the 250 volts available at switch contacts 1 and 3 is applied to the coils of relays K101 and K2. The contacts of relay K101 complete the tone path to the contacts of relay K2, and with relay K2 operated, the tones reach the audio amplifiers. Because K2 is operated, relay K3 also closes. Relay K3 completes the audio output circuit to the modulator, causes the indicator lamp to light, turns on the transmitter, and mutes the microphone. The group-call tones are transmitted for as long as the operator holds down the group-test button. After four seconds, however, the receivers should be alerted. The desired message may now be sent.

Meanwhile, at the Receiver . . .

The basic QUIK-CALL section of the receiver is shown in figure 5. Depending upon the switch in the hang-up box, the audio at the secondary of the output transformer may be applied to the speaker or it may be applied to the QUIK-CALL unit.

If the microphone or handset is off the hook, the audio (available at terminal 46) is applied through contacts D and C of the switch to terminal 45. From terminal 45 the path proceeds through jumper JU-1 to the speaker. Thus, if the hook in the hand-up box is "up," the receiver output will be applied directly to the speaker. QUIK-CALL control is possible only when the handset or microphone is on the hook.

In normal QUIK-CALL operation, then, the audio path does not lead directly to the speaker as described above, but rather through contacts D and E of the switch to terminal 42. From terminal 42 the audio goes to terminals G and F of relay K1 and on to the four vibrasponder coils.

The only way in which the audio can now reach the speaker is for the relay to be operated. The audio then finds a path to the speaker through relay contacts F and E. The relay is energized only if the correct tones are received. When this occurs, the vibrasponders complete the circuit (partly shown in the figure), which causes the tube to conduct and operate the relay.

The length of time that the relay remains energized depends upon the position of the "lock-nonlock" switch. With the switch in the "nonlock" position, the timing circuit will keep the relay operated for about 7 seconds; in the "lock" position, the relay stays energized until the operator removes the mike from its hook.

With a QUIK-CALL signal coming into the receiver, the pulses quickly capture the circuit and cause the relay to close. The operator will usually hear the end of the second pulse transmission. Or, if the received signal is weak so that the second pulse just opens the receiver at the end of the pulse, the operator will hear the squelch tail (if the operator at the base station does not keep the transmitter "on the air"). In this way, the operator is alerted to an incoming message before the message is actually sent.

If the operator does not complete his message during the seven seconds following the second pulse, and if the operator at the receiver does not remove his microphone, the relay opens at the end of this period, and the receiver is effectively "dead." (We are assuming that the function switch is still in the nonlock position.)

If the receiver QUIK-CALL switch is placed in the "lock" position, however, once the relay has been closed by the tone pulses the relay will remain locked-in until the operator removes his microphone from the hook. The lock-in position of the switch places the grid at near-cathode potential, through relay contacts A and B, thereby allowing the tube to conduct until the microphone is removed. With the microphone off the hook, the right-hand terminal of the relay coil is grounded through its contacts A and B, and contacts A and B of the hang-up switch. With both terminals of the relay coil grounded, the relay releases.

Terminals C and D of the relay "make" when the relay operates, and they can be used to close a circuit which operates a horn, lights a lamp, or performs a similar function. Thus the operator who has been away from the receiver knows that he has been called. For this function, the switch must be placed in the "lock" position.

The Vibrasponder Circuit

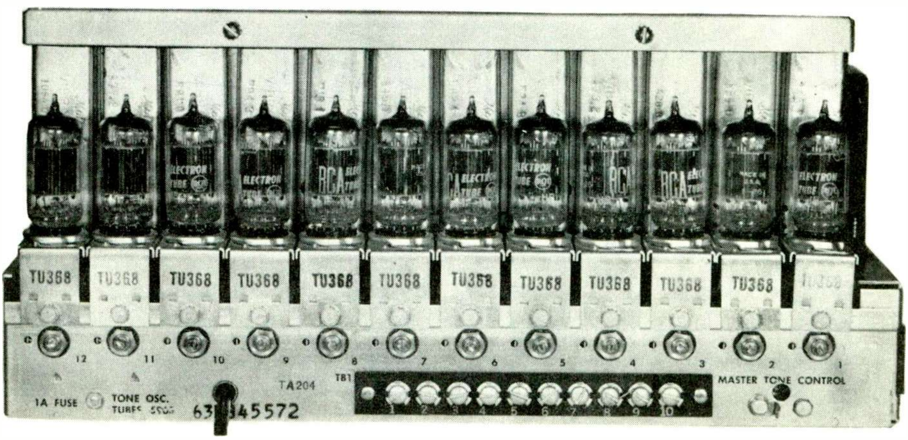
Figure 6 is a complete diagram of the QUIK-CALL unit required at the receiver. For QUIK-CALL operation, four vibrasponders control the conduction of the tube, V1, and the latter determines the operation of control relay K1.

Both triode sections of V1 are initially biased so that there is but little conduction. Relay K1 in the cathode of the right-hand section will not operate, therefore, unless that triode section is made to conduct heavily. This is accomplished by making the grid positive. As we shall see, this positive voltage originates at the plates of V1.

The QUIK-CALL tones from the receiver output transformer are applied to the four coils of the vibrasponders through contacts F and G of relay K1. The tones of the first pulse must correspond to the frequency of the vibrasponders installed at E1 and E2. Assuming that this is the case, the reeds of these two vibrasponders close their "B" contacts.

Although the reed contact is intermittent, the action of the RC circuit in parallel with the contacts produces an almost steady DC voltage as the reed continues to vibrate.

The B+ voltage (present at the plates of the tubes) is applied through the vibrating reed contacts of both vibrasponders to the grid circuit of the left-hand triode. This voltage is applied to the junction of resistors R1 and R2, and charges the grid capacitor, C1, to a high DC voltage. The discharge of this capacitor, however, is through R1 and R2 in series, so that the time constant is long and the grid is kept positive for some time.



Here We See the Twelve Tone Generators, Vibrasenders, and Level Setting Adjustments, all Part of the Quik-Call Base Station.

When the grid of the tube swings positive, the tube conducts heavily and almost all of the supply voltage appears across the large cathode resistor, R3. This high positive voltage is used to unbias the grid of the right-hand triode.

Assuming that the second pulse corresponds to the frequencies of vibrasponders E3 and E4, contacts "B" of both these vibrasponders close. The positive voltage from the cathode of the first triode then charges capacitor C2 in the grid circuit of the right-hand triode. This makes the grid positive and the tube conducts. The cathode current passes through the coil of relay K1, causing the relay to operate. The charged capacitor (C2) in the grid of the triode discharges through the large resistor in parallel with it and, because of the long constant involved, the grid holds the tube conductive for about seven seconds (with the switch in nonlock position).. The relay contacts are closed during this time and the operator hears all messages that may be sent.

If the switch is in the "lock" position, however, the relay remains operated until the microphone is removed from the hang-up hook. With the switch in the lock position, the grid is returned to the top of the relay coil through relay contacts A and B. After capacitor C2 has discharged, the only remaining bias on the stage is that developed by the small cathode resistor, R5. This allows the stage to continue to conduct normally and the relay remains energized. When the microphone is removed from its hook, the blue wire leading to terminal A of the relay is grounded; with contacts A and B closed, the top of the relay (terminal J) is grounded, so the relay must release.

Receiver Group-Call Operation

Only two tones, common to a group of receivers, are required for group-call. These tones must correspond to the frequencies of the vibrasponders installed in sockets E2 and E3 (fig. 6). To alert the receivers within a group, the operator sends these common tones for a period of four seconds. These group-call tones energize vibrasponders E2 and E3 at the receiver, closing their "B" contacts and applying the plate supply voltage to grid capacitor C2 through the contacts of vibrasponder E2, R7 (3.9 megohm), and the contacts of vibrasponder E3. The tones must be continuous for approximately four seconds, as it requires this much time for the vibrasponders to operate and for capacitor C2 to charge through the high resistance of R7. After four seconds, however, all receivers which have the proper group-call tones will have been alerted. The desired message may now be sent simultaneously to all the receivers of this group.

Where group-call operation alone is desired, only two vibrasponders need be installed in the E2 and E3 sockets. (In earlier models, the wiring of E2 and E3 was different

Here We See a Quik-Call Console Utilizing High-Frequency Coding Tones (Evidenced by the Letters on the Push-Buttons).

and all four vibrasponders were required to complete these circuits.)

Level Adjustments

Although the levels of the various oscillators used with QUIK-CALL equipment are adjusted at the factory, it is important that they be readjusted (checked) according to the requirements of the system being used. Transmitters may differ as to the modulation voltage required for the same amount of deviation, and control lines have various voltage drops. It is thus necessary to adjust the tone levels for a deviation which will produce sufficient voltage at the receiver output to operate the vibrasponders. In making any level adjustments, we are thus interested in the voltage produced at the receiver rather than in the modulating voltage to the transmitter.

The various vibrasponder assemblies at the receiver require different voltage levels to produce positive operation of the reed. These levels will be found in a chart such as that of figure 7.

At the back of the QUIK-CALL console there is an adjustment for each of the individual tone outputs, plus a master tone control. The output adjustment for the separate tones are numbered from 1 to 12 and correspond to the 12 tone generators, regardless of which vibrasender is installed in the socket.

If the particular system uses high-band tones (usually the case in almost all new installations), the first steps are (1) to adjust the individual tone level for tone number 12 (labeled "P") and (2) to adjust the master level for the desired receiver output. Then, leaving the master adjustment at one setting, we adjust the remainder of the tone generators for the recommended output.

An AC voltmeter is connected at the audio input to the QUIK-CALL unit, and the receiver is unsquelched (squelch control fully clockwise). The receiver audio level control (located on the receiver chassis--not the volume control on the control head) is advanced until the reading on the meter, due to noise, is between 0.8 and 1.0 volt. The receiver is then squelched and the level adjustment for tone 12 (P) is set to approximately three-fourths maximum. The master tone control is then adjusted for a reading of 2.2 volts on the meter. (The

Here We See the 32-Button Accessory Box Connected to the Quik-Call Console.

master tone control should not be changed after this; the control for tone 12 also needs no further adjustment.) The individual tone levels may now be adjusted according to the voltage values indicated in figure 7.

Where low-band tones are used for a particular system, the level of tone number 1 is first adjusted by placing the individual tone control at three-fourths maximum and adjusting the master control to 0.70 volt. The individual levels are then adjusted according to the chart, as before.

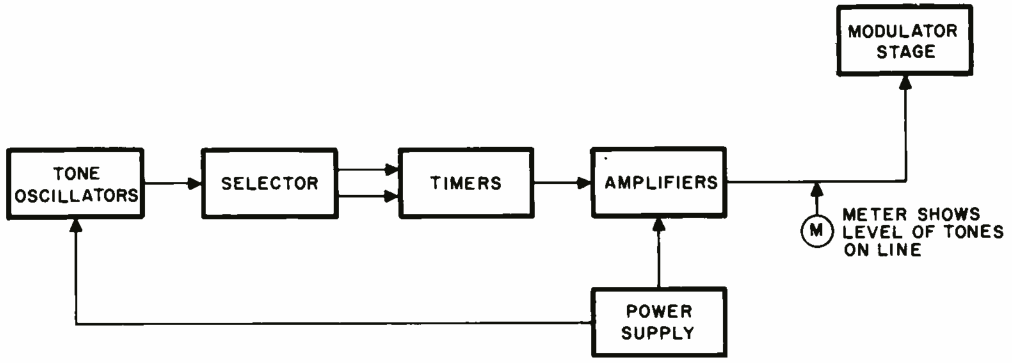
The meter on the QUIK-CALL selector panel is not to be used in adjusting the tone levels. This meter merely indicates the level of the voltage at the console. It does not show the amount of deviation produced nor does it tell how much voltage is applied to the vibrasponders at the receiver.

Accessory Selector Box

A 32-button selector box may be used as an accessory to the QUIK-CALL console described in this lesson. This additional selector box may plug directly into the console or it may be remotely located, with an interconnecting cable between the two units. This selector box facilitates the selection of QUIK-CALL groups or group-calls by requiring only one button to be depressed for any one call. Connections may be made so that one button will initiate a QUIK-CALL function (or a group-call) without any thought as to timing. The timing is performed by the circuitry within the selector box. This piece of equipment allows as many as 32 different calls to be made, requiring only one button to be depressed for each. A red indicator lamp shows when a transmission is taking place or when the console is being used.

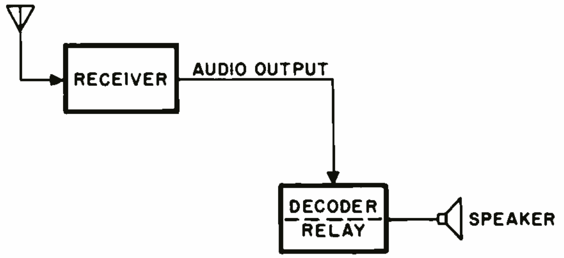
STUDENT NOTES

STUDENT NOTES



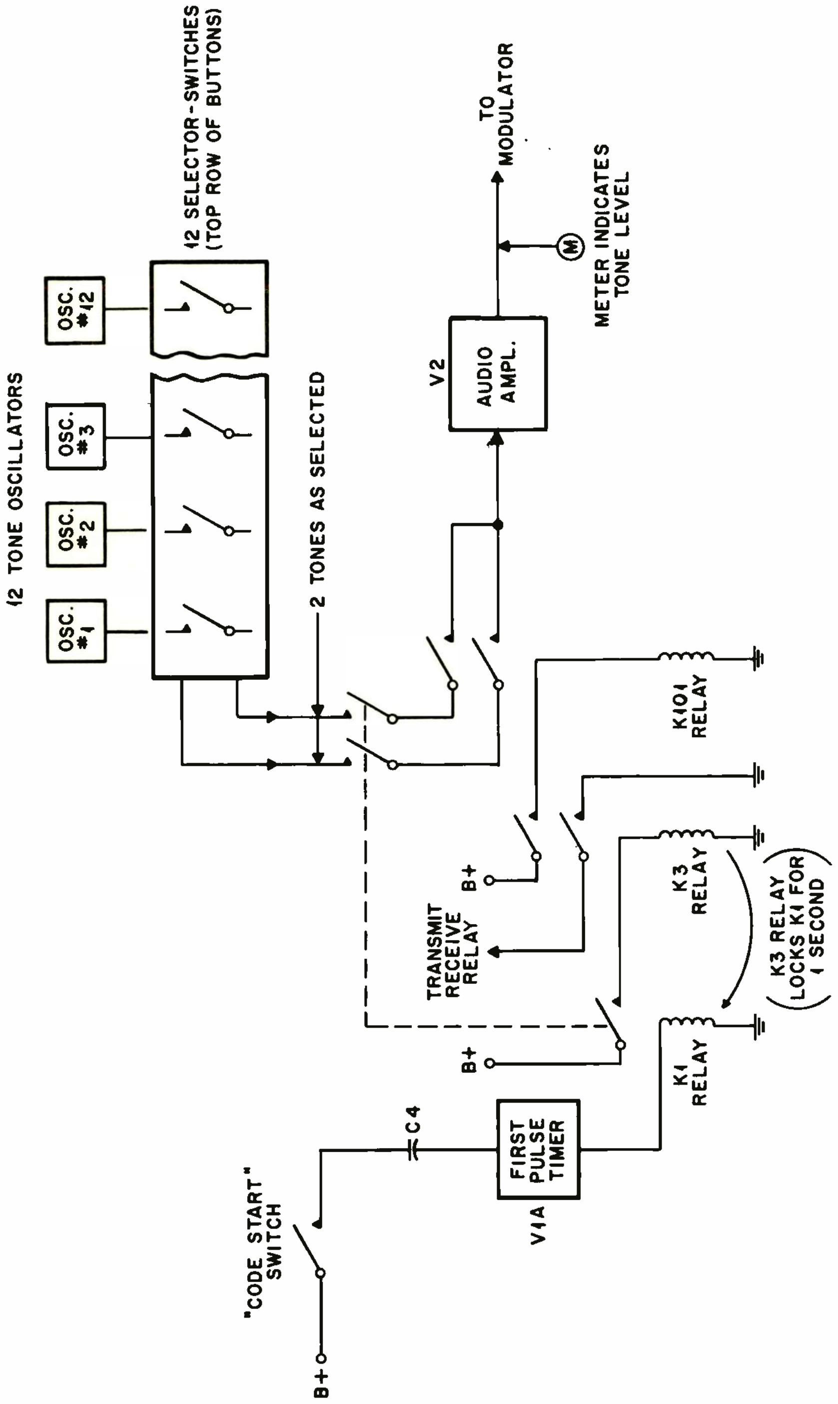
TRANSMITTER
QUIK-CALL SYSTEM

FIGURE 1A

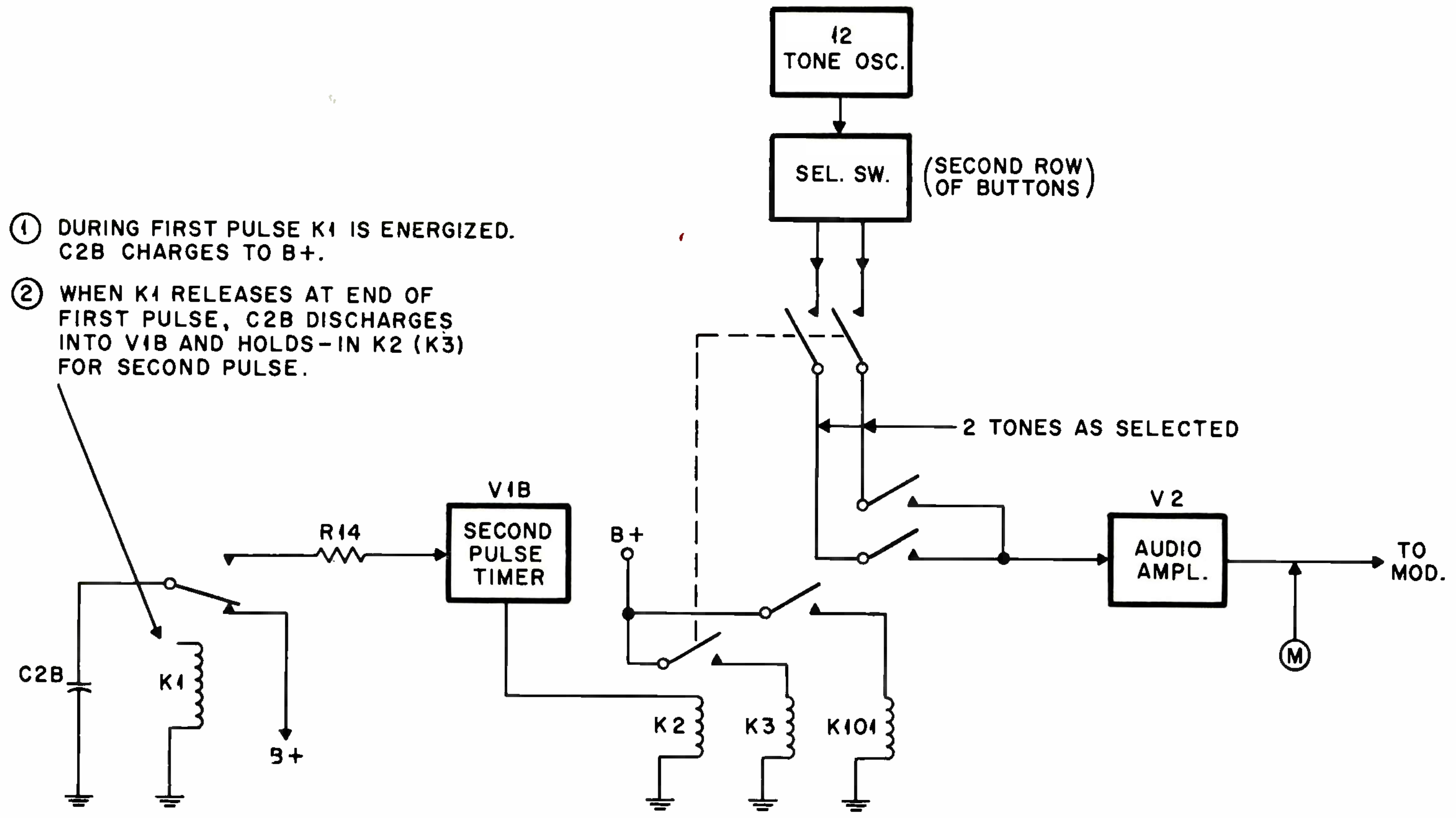


RECEIVER
QUIK-CALL SYSTEM

FIGURE 1B



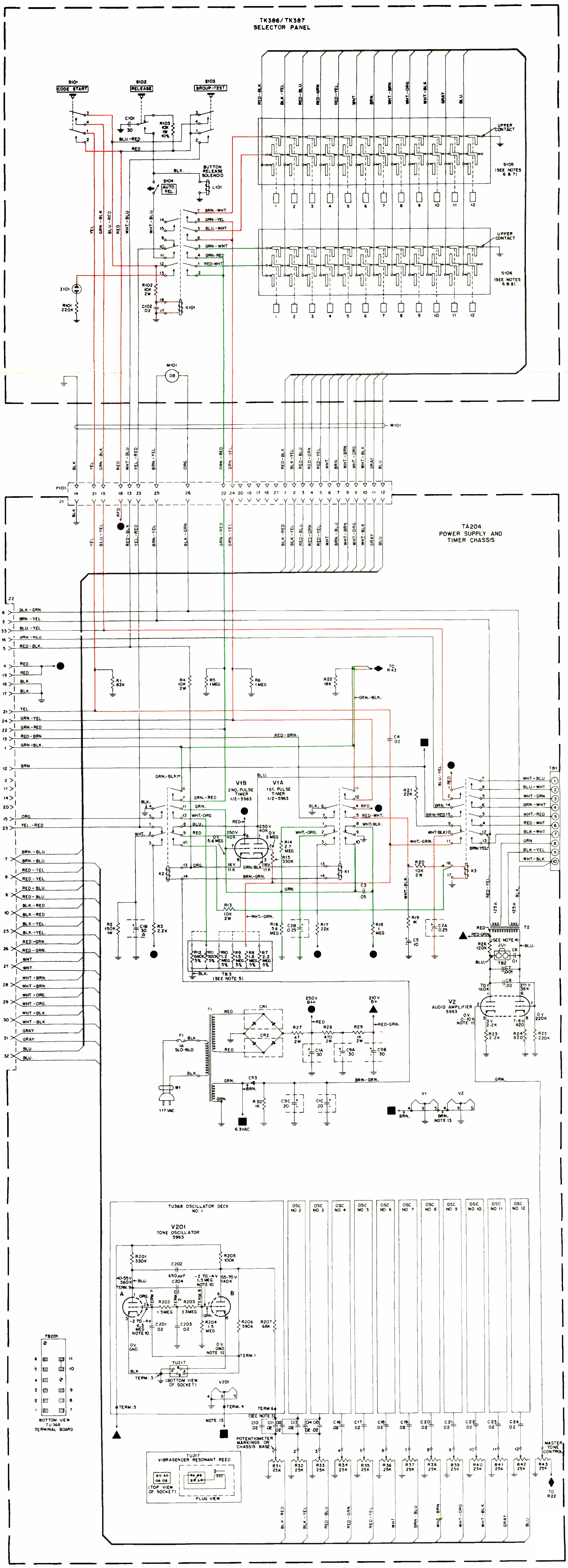
FIRST PULSE TRANSMISSION
FIGURE 2



SECOND PULSE TRANSMISSION

FIGURE 3

STUDENT NOTES



TA203 SERIES QUIK-CALL CONSOLE

FIGURE 4

TONE ADJUSTMENT TABLES

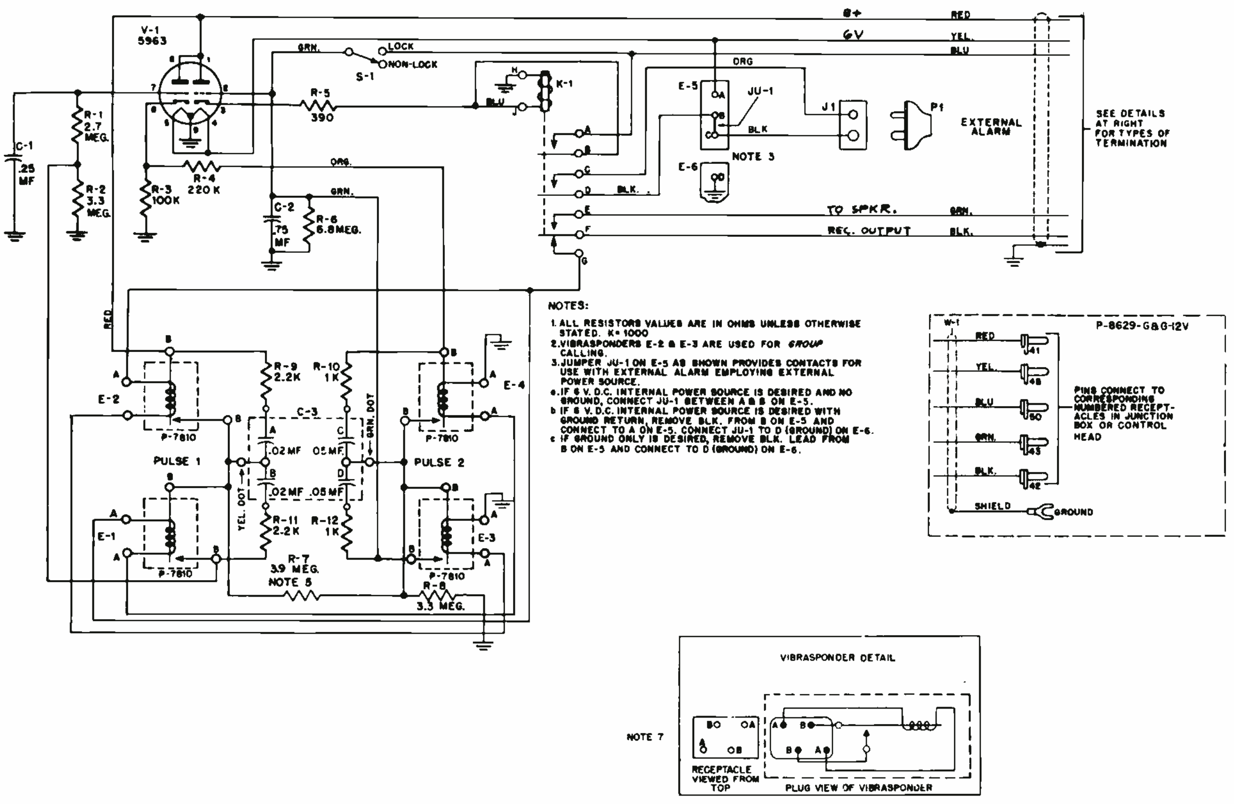
LOW BAND TONES (100 to 312.6 cps)

Push-Button	Tone Level Control	Voltage
1	1	0.70
2	2	0.62
3	3	0.53
4	4	0.53
5	5	0.53
6	6	0.58
7	7	0.65
8	8	0.72
9	9	0.79
0	10	0.88
A	11	0.98
B	12	1.08

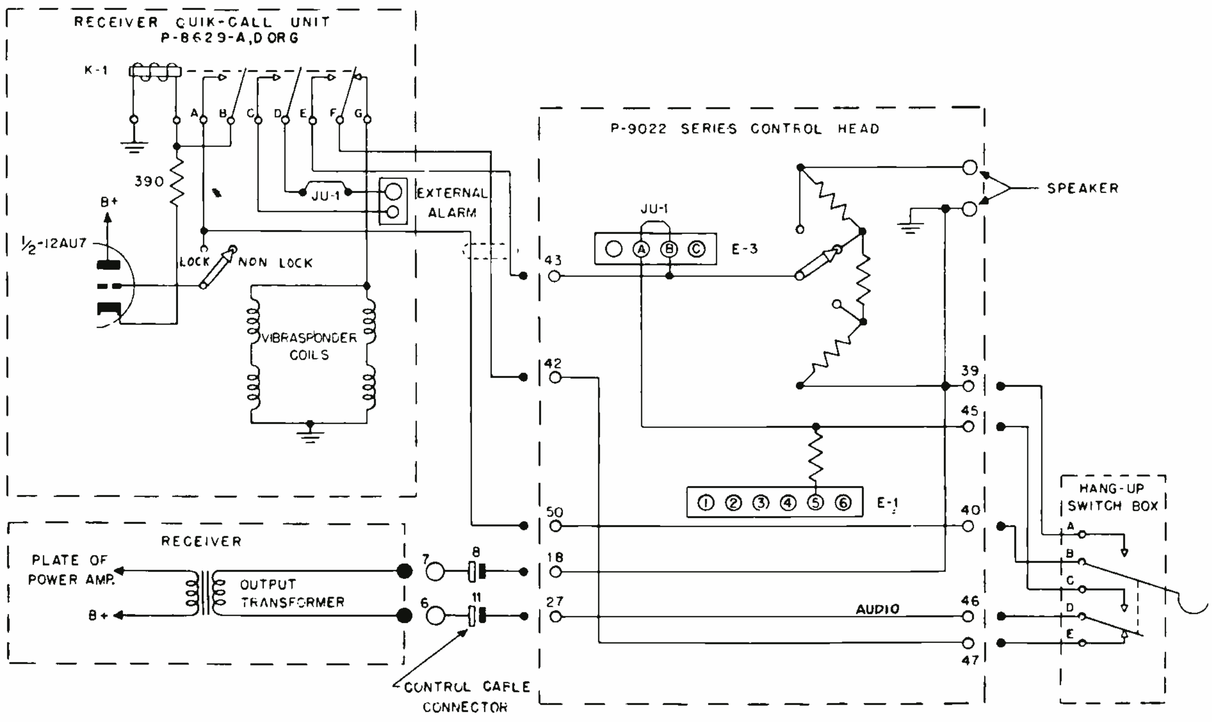
HIGH BAND TONES (346.7 to 1084 cps)

Push-Button	Tone Level Control	Voltage
C	1	1.4 v.
D	2	1.5 v.
E	3	1.6 v.
F	4	1.7 v.
G	5	1.8 v.
H	6	1.9 v.
J	7	2.0 v.
K	8	2.1 v.
L	9	2.2 v.
M	10	2.2 v.
N	11	2.2 v.
P	12	2.2 v.

FIGURE 7.



RECEIVER QUIK-CALL CONTROL CIRCUIT
FIGURE 6



NOTES:

1. THE MICROPHONE OR HANDSET IS SHOWN ON THE HOOK. SPEAKER CIRCUIT IS OPEN.
2. WHEN USING MILITARY MICROPHONE, JUMPER JU-1 MUST BE USED BETWEEN "A" & "B".
3. WHEN USING HANDSET, JU-1 BETWEEN "A" & "B" PUTS HANDSET IN PARALLEL WITH SPEAKER.
4. WHEN USING HANDSET AND NO JUMPER, HANDSET EARPIECE IS OPERATIVE AND SPEAKER IS MUTED EXCEPT FOR SELECTIVE CALL SIGNAL.
5. LETTER DESIGNATIONS ON HANG-UP SWITCH BOX ARE FOR REFERENCE ONLY.

RECEIVER QUIK-CALL
SIMPLIFIED CIRCUIT OPERATION
FIGURE 5

national

MOTOROLA

RADIO COMMUNICATIONS

service

A TWO-WAY RADIO COMMUNICATIONS TRAINING PROGRAM

LESSON MA-1
SPECIAL SYSTEMS

Private Line Systems

MOTOROLA TRAINING INSTITUTE

A TWO-WAY RADIO COMMUNICATIONS TRAINING PROGRAM

LESSON MA-1
SPECIAL SYSTEMS

Private Line Systems

—one of a series of lessons on two-way FM communications—

MOTOROLA TRAINING INSTITUTE
4501 W. AUGUSTA BLVD., CHICAGO 51, ILLINOIS
APPROVED BY THE STATE OF ILLINOIS
DEPT. OF REGISTRATION AND EDUCATION

PREFACE

This is one lesson of a complete Motorola Home-Study Course which presents to the Service Technician both the principles of operation and the maintenance of two-way FM radio systems. The program covers mobile, portable and base station equipment, including the latest transistorized units.

TWO-WAY COMMUNICATIONS

PRIVATE LINE SYSTEMS

LESSON MA-1

TABLE OF CONTENTS

NOTICE

Diagrams and figures referenced in text are "fold-outs" in back of each lesson, for use while studying. The Examinations are also there.

Like service organizations in other fields, those involved in the maintenance of two-way radio also realize the many advantages of having two-way radio.

TWO-WAY COMMUNICATIONS
PRIVATE LINE SYSTEMS

Lesson MA-1

Introduction

We have previously referred to the crowded conditions associated with two-way mobile communications, and we pointed out that this congestion has been growing continuously, so that many services are today compelled to share the same channel. Several taxicab companies for example, may find themselves required to use the same channel, if they wish to have two-way communications.

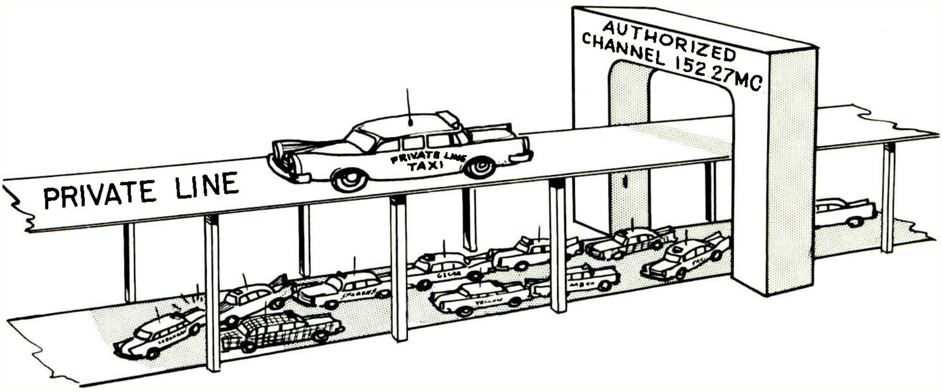
Under these conditions, with the usual carrier-operated squelch, the mobile operator must listen to all messages on the channel, although only a small percentage of them may be directed to him. This is very bothersome.

One solution to this problem is to use Motorola "PRIVATE LINE" radio equipment. With this equipment, the only time any sound reaches the loud-speaker is when the carrier belongs to one of the stations within the system. The speakers are silenced at other times. As soon as a "system" transmitter comes on the air, however, the receiver squelch is opened and the receiver is subject to the same operating conditions as any other receiver.

Private Line radio operation is achieved by means of a unique squelch system which silences the audio section of the receiver. The squelch is not operated by the carrier and noise reduction, as is usually the case, but by a low-frequency audio tone which constantly modulates the carrier. This audio tone is below the voice range of 300-3000 cps, however, and special filters are used to eliminate it in the audio stages of the receiver. By means of highly selective circuits and a high-Q vibrating reed, the squelch is made insensitive to all audio frequencies except that one to which it is tuned. Ten audio frequencies (between 100 and 136.5 cps) are available for this purpose. Another reed is incorporated in the transmitter, and its frequency must be the same as that of the reed in the receiver. It is thus possible to have as many as ten different systems on the same channel and still maintain "Private Line" radio operation for each system.

Advantages of Private Line Operation

The main advantage of Private Line radio operation, as we have



Although Private Line Radio is on the Same Channel and in the Vicinity of Other Systems, it Effectively Provides a New and Nuisance-Free Channel.

just seen, is that the operator is freed from the necessity of listening to all the messages of other systems operating on the same channel.

Another advantage of Private Line radio systems is that the equipment is continuously operated at full squelch sensitivity. With the conventional squelch system the sensitivity of a receiver squelch is subject to the setting of the squelch control. With the correct setting of this control, a weak signal will open the squelch. If the squelch control is advanced too far, however, the squelch sensitivity is lowered and this same signal may not be strong enough to open the squelch circuit.

The tone-operated squelch permits the sensitivity of the receiver to remain at its full value; the squelch setting is not adjustable. In Private Line radio operations, the squelch will always be open for the weakest signal that is readable.

With his receiver squelched and in the absence of the carrier with its correct squelch tone, the operator is not only relieved from the necessity of listening to other signals on the same channel, he is also oblivious of interference signals, intermodulation and image response. Such "interference" may still be taking place in the receiver circuits, for this portion of the receiver is operating at all times, but the speaker is silenced and the operator does not hear it. As soon as his receiver is activated, by the correct carrier and tone squelch, however, it will operate in a normal manner, being subject to all the interference signals listed above.

Basic Principle of Operation -- Transmitter and Receiver

Figure 1 shows the block diagram of a Private Line transmitter which is designed to operate in the high band (144-174 mc). The same system is also used for low-band (25-54 mc) and 450-mc equipment.

The transmitter block diagram is the same as that previously studied with the exception of the tone oscillator (TK 349), which generates a low frequency audio tone, somewhere between 100 and 136.5 cps. The exact frequency is determined by the reed installed. Motorola uses the term "VIBRASENDER" to identify this particular oscillator reed.

The tone oscillator output is applied to the phase modulator together with the audio modulation. Hence, the coding tone will be present at the transmitter output as long as the equipment is on the air.

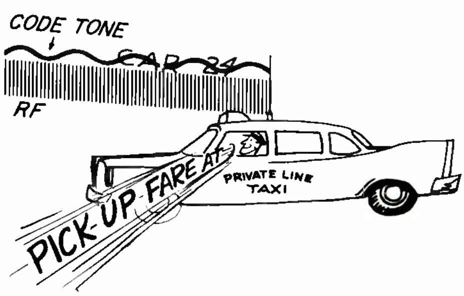
Figure 2 shows the block diagram of a Private Line receiver. To be consistent with the transmitter of figure 1, the diagram is that of a high-band receiver. The entire front-end, low-frequency IF, limiter and discriminator sections of the receiver are the same as for any conventional receiver. The point of difference in this Private Line receiver, however, is to be found in the squelch circuitry. The discriminator output contains the audio message which is to be reproduced; it also contains the Private Line tone signal. This output is applied both to the low-pass amplifier and to the audio amplifier. Filters in the low-pass amplifier reject the higher audio signals, passing only those frequencies below 300 cps. The coding tone thus reaches the limiter amplifier where it is further amplified. The amplification is sufficient to properly drive the resonant reed, which Motorola calls the "VIBRASPONDER."

When the correct tone is received, the reed is energized, closing contacts so as to apply the negative DC bias voltage from the limiter to the grid of the DC amplifier stage. This negative voltage disables the squelch, allowing the receiver audio section to operate normally. When the correct tone is not present to operate the vibrasponder, the negative voltage from the limiter does not reach the DC amplifier, the squelch is closed, and the receiver is silent. Thus, the only time that the receiver audio section is operative is when a tone of the proper frequency is received.

The highest frequency used for the audio tone (136.5 cps) is considerably lower than the audio voice range used in two-way communications (300-3000 cps). It is therefore improbable that any normal voice transmission will open the squelch of the Private Line receiver.

Transmitter Circuit Analysis

Figure 3 shows the complete schematic of the tone oscillator used in a typical Private Line transmitter. The output of this oscillator is applied to the modulator so that the RF carrier will be modulated by the coded audio tone signal whenever the transmitter is on the air, and this signal operates the squelch in the receiver. A triode-pentode tube (V201) is used as a resistance coupled type of oscillator, with the Motorola Vibrasender resonant reed controlling the frequency. This reed is a very high-Q device and it has a frequency stability of .15% over a temperature range of -20° to + 80°C. Because of its high Q, it is a relatively slow starting device and it would interpose a time delay if it were operated during transmission periods only. Instead, the B supply is present at all times and the tone oscillator is kept in constant operation. With this arrangement, the tone modulates the signal as soon as the transmitter is operated.



Only Those Channel Signals Which Contain the Proper Code Tone are Heard in the Private Line Receiver.

The output of V201A is coupled to the grid of V201B. The plate circuit of V201B is fed back to the grid of V201A, through R202 and C201. The operation of this circuit is similar to that of a multivibrator.[1] The vibrasender reed acts as a frequency controlling device in the grid circuit of V201A. The coil energizes the reed, which vibrates at its natural frequency. The vibrating reed induces a voltage in the coil which is connected between grid and ground, and the operating frequency of the oscillator is thus controlled.

Automatic gain control, for a constant output voltage, is obtained from the grid of V201B. The grid-leak voltage developed across R209 is fed to the grid of V201A, limiting the gain and output of the oscillator. Capacitor C206 between the two plates prevents the circuit from oscillating at higher frequencies. The negative feedback resulting from C206 helps produce a nearly sinusoidal output waveform. There is also a low-pass filter (R207, C205) in the output line to the modulator, and this filter has an attenuation characteristic of 6 db per octave.

The two cathodes are connected to ground only when the vibrasender assembly is plugged into its socket. This prevents the oscillator from operating at some random frequency if the vibrasender should be removed. In order to change from one control or coding frequency to another, all that is required is to replace the reed assembly with one having the desired frequency.

If the carrier deviation due to the coding signal should become too great, the higher voltage in the receiver audio circuits will cause

1. See TM 11-672, pages 59-84.

a hum at a harmonic of the frequency of the coding signal. Insufficient deviation, however, may not produce sufficient voltage to operate the Vibrasponder. Optimum operation is obtained when the deviation is between 1 and 2 kc, and the tone oscillator is designed for an output voltage sufficient to produce this deviation. There is no output adjustment by which the serviceman can control the output voltage, but it is held nearly constant by the AGC action already described.

The Private Line receiver circuitry in figure 4 corresponds to the block diagram of the receiver, shown in figure 2. This is only a partial diagram, but the remaining part is the same as any conventional receiver.

The audio input from the discriminator (upper right) goes both to the audio amplifier, V112B, and to the low-pass amplifier, V112A. By means of C153, C155 and C156 between the input and V113A, the voice frequencies are attenuated, only the coding frequencies reaching the vibrasponder driver stage (V113A) with any magnitude. The vibrasponder amplifier is in reality a limiting amplifier, operating at the saturation level for normal coding signals. Thus the drive (for the vibrasponder in the plate circuit) is controlled and remains constant for all normal operating conditions of the equipment. The high Q of the Vibrasponder prevents it from operating for any coding signal other than that of the natural vibrating frequency of the reed. When a signal having the correct frequency is applied, the reed vibrates vigorously, closing the contacts, B-B. This is an intermittent contact, but the filtering network (R148, R147 and C159) applies a nearly constant DC to the grid of the DC amplifier control tube (V113B). This negative voltage comes from the grid of the first limiter stage (not shown in figure 4).

The negative bias at the grid of the DC amplifier is sufficient to prevent that tube from conducting. The squelch is thereby opened and the audio stage may now operate normally. Basically the action is as follows:

The grid of the audio amplifier V112B is at the same DC potential as the plate of the DC control tube 113B. (This is effected by the DC path from the plate to the grid, through the tone filter). When V113B is conducting, its plate potential is low. This leaves the grid of V112B negative with respect to its cathode and cuts off the plate current in this tube. When the grid of V113B is made negative, this tube no longer conducts and its plate potential rises, making the grid of V112B less negative with respect to its cathode. The audio stage (V112B) may now operate normally.

In order to prevent a tone hum in the speaker, it is necessary to prevent the coding tone from reaching the plate circuit of the audio amplifier, V112B. Considerable attenuation of the lower frequencies is provided between the discriminator and the amplifier input, and the tone filter offers negative feedback between the plate and grid of the amplifier. As a result of this arrangement, the over-all amplification of the stage is very low for the frequencies within the coding frequency range, but normal amplification is provided for the voice frequencies. From V112B, the audio is applied to the power amplifier and thence to the speaker.

The cathode of the output stage is grounded in the normal manner for mobile installations but further provision must be made for reduction of hum which may be remaining in the output of the base station receiver. (This hum is too low to be noticed in mobile equipment, but it may be heard under quiet monitoring conditions such as encountered in base station operation.) This is accomplished by making the cathode circuit degenerative at the low audio frequencies -- those below the voice range. To perform this task, a filter having a high impedance at the low frequencies is inserted between cathode and ground to obtain inverse feedback. The output stage thus provides very little amplification for voltages present at the coding frequency range, but operates in the normal manner for voice frequencies.

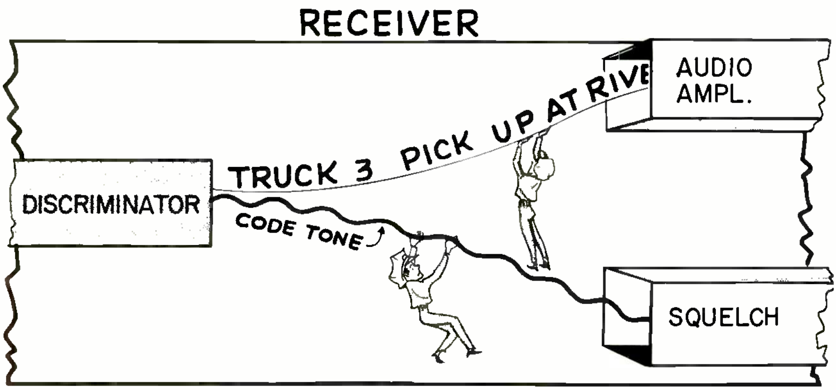
The Private Line receiver may be operated as Private Line radio equipment by grounding the cathode of the DC control tube. This is facilitated by a switch which is mounted on the control-head (not shown in figure 4). If the cathode is opened at the switch, the squelch circuit is disabled and it cannot quiet the receiver. With his speaker on constantly, the operator may monitor all signals within the channel, or as a quick check of his receiver's operation. When no carrier is present, there is no squelch to provide receiver silencing, and the characteristic hiss, or FM receiver noise will be heard.

The Private Line radio squelch remains open as long as the correct carrier is being received, because the latter is modulated continuously by the tone oscillator at the transmitter. Other carriers (not having the correct coding signal) will not operate the squelch, and the receiver remains silenced.

Squelch Tail

When a transmission is completed and there is no longer any carrier present to provide quieting, the squelch might be expected to close, silencing the receiver. It is true that as soon as the squelch circuit goes into operation the receiver is silenced, but in actual practice the time constants of the squelch circuitry will keep the audio section of the receiver open for a short period of time after the carrier is removed. In the absence of a carrier to provide quieting and with the squelch still open, the typical FM noise reaches the speaker. This short burst of noise which is heard in the speaker as the carrier is removed is known as "squelch tail" and it is a common characteristic of communications receivers which are equipped with carrier operated squelch circuits.

at the transmitter a short time before the carrier is discontinued. During the period that the squelch requires to close, the carrier is present to provide quieting. By the time the carrier goes off the air, the receiver is already silenced by the squelch. Squelch tail is thus eliminated by controlling the transmitted signal rather than by any circuitry within the receiver. The operation can be seen by studying figure 5.



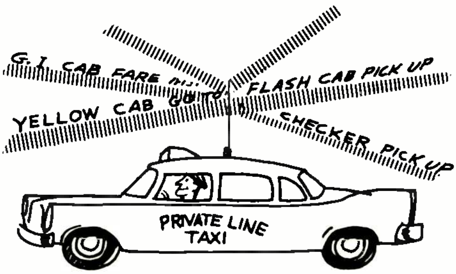
Inside the Receiver the Code Tone is Separated from the Message and Applied to the Squelch Circuit. The Correct Code Tone Causes the Squelch to Open, and the Message Reaches the Speaker.

Squelch tail can be a real source of annoyance in Private Line receivers, where the vibrating reed of the Vibrasponder due to its high "Q" tends to keep the squelch open for a still longer period of time. Special circuitry incorporated in Motorola Private Line radio equipment eliminates this squelch tail.

Squelch Tail Elimination

One simple way to eliminate squelch tail in Private Line radio is to remove the tone modulation

Figure 5 shows the control circuits of the entire equipment, with the control relays in the transmit position. The two squelch-tail controlling relays (K2 and K3) on the squelch-tail eliminator chassis (which is located on the power supply chassis) are energized whenever a ground is supplied at the "B" contact of K3. This connection is made at terminal 16 of TB2. The line may be grounded (1) by the push-to-talk switch on the microphone, or (2) by energizing the transmit-receive relay (K1) on the remote control chassis. Grounding this line completes the path through both relay coils and through the time delay network to a source of continuous B+ voltage (the receiver plate supply). With both relays now energized, they perform the following functions:



The Many Nuisance Messages of Other Systems on the Same Channel are Not Heard in the Private Line Receiver.

Contacts 3 and 4 of relay K3 open, ungrounding the output from the tone oscillator. (While the tone oscillator, which is located on the transmitter chassis, is in continuous operation, its output is grounded whenever relay K3 is de-energized and the tone cannot reach the phase modulator of the transmitter.) With K3 now energized, the tone oscillator output is present at the phase modulator. Relay K2 is also energized, grounding contact 1 through contact 2. This energizes the transmit-receive relay, K1 placing the transmitter in operation. The transmitter is now "on the air" and ready for voice modulation. The carrier is continually modulated with the coding tone, and the receiver squelch has been opened by this tone. We are now ready to see what happens when the operator releases his push-to-talk switch.

As soon as the operator is through with his message he releases the talk switch, breaking the ground connection to relays K2 and K3. Relay K3 releases immediately and the tone output from the tone oscillator is grounded. With the coding tone no longer present at the receiver, the squelch starts to close. This is not an instantaneous action as we have already explained, but there is no squelch tail heard at the receiver, because the carrier is still being received.

Although relay K2 is in series with K3, it does not release at the same time. During the time that K1 of the Remote Control chassis was energized, capacitor C2 was charged, to the voltage across K2. It now starts to discharge through the time-delay network and through the coil of relay K2. The time constant of this circuit will cause relay K2 to stay energized longer than K3. The time delay network will, when adjusted for the proper delay time, hold the relay closed until the squelch in the receiver has had time to operate.

Relay K2 now opens and the ground is removed from the coil of K1. This relay (K1) now releases and shuts off the transmitter (removes the carrier). By this time, however, the receiver squelch has closed and no noise (squelch tail) is heard in the speaker.

Before leaving figure 5 there are several other circuits shown on this schematic which warrant inspection, since they affect the squelch-tail operation of the equipment. When relay K2 releases, contacts 3 and 4 are closed, placing capacitor C2 in parallel with one of the 33K resistors. These resistors are connected as a voltage divider across the receiver B+ supply and a constant voltage is applied to them. The capacitor is thus charged at the time it is placed across the coil of K2. Whenever the operator momentarily presses his push-to-talk switch, and releases it, the capacitor will hold K2 closed, preventing a squelch tail at the receiver. Without such an arrangement, this quick on-and-off action might fail to provide the necessary charge for the capacitor and relay K2 (and K1) would make and break immediately, resulting in a squelch tail at the speaker.

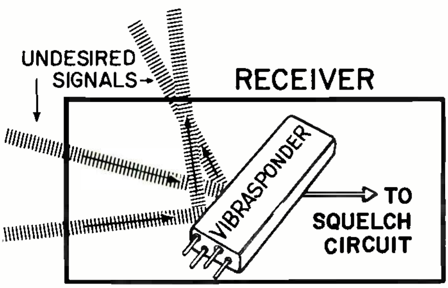
The "Tone oscillator B+ stabilizing network" compensates for B supply voltage changes which occur when the equipment is switched from receive to transmit, and vice versa. During transmission periods, the load on the receiver power supply is greatly reduced and the voltage supply to the tone oscillator increases. However, with contacts 4 and 5 of relay K1 open, a voltage drop is provided by the 6.8K resistor in the supply line to the tone oscillator; this voltage drop is further increased by the 56K resistor which is placed parallel to the line. During receiving periods, the B supply voltage decreases, but the voltage at the tone oscillator remains nearly constant. When it releases, the relay "makes" contacts 4 and 5, placing the two resistors in parallel with each other and in series with the tone oscillator supply line. This means less resistance and less voltage drop across the resistors, which in turn means a steady voltage applied to the oscillator, and the operation is stabilized. Any sharp change in supply voltage would produce undesirable transients in the tone oscillator and impair operation of the equipment.

The squelch tail eliminator shown in figure 5 still has one significant shortcoming--it takes too long for the transmit-receive relay to place the receiver back in operation after the operator has released the "talk" button. Let us suppose that the operator of station number 1 has been talking to station 2. As soon as the message is completed, the operator at station 2 pushes his talk button. The equipment, however, due to the delay circuitry, has not yet returned to the receive position, and operator No. 1 does not hear the beginning of the other operator's reply. It thus becomes desirable to shorten the time it takes a station to return to receive operation, at the same time providing positive squelch-tail elimination at the receiver. This "fast acting" feature is accomplished by means of the circuitry shown in figure 6.

Fast-Acting Squelch Tail Eliminator

The Motorola squelch-tail eliminator shown in figure 6 is fast acting, allowing almost instantaneous call-back from one station to another.

This arrangement provides quick squelch action at the receiver, which allows a quicker release of the transmit-receive relay at the transmitter. By bringing the Vibrasponder to a quick stop, the receiver squelch circuit will close in a shorter period of time. To accomplish this, a tone signal of the same frequency but of an opposing phase is sent out on the carrier and this signal tends to make the reed vibrate in the opposite direction, thereby damping its action. When the reed is sufficiently damped to prevent its contacts from completing the circuit, the carrier can be removed at the transmitter.



At the Private Line Receiver, Undesired Signals Cannot Operate the Vibrasponder and Cause the Squelch to Open.

The transmitter in figure 6 is turned on whenever squelch-tail relay K2 is energized. Relay K2 has two sets of contacts (both sets shown in the released or receive position in figure 6). When K2 is energized (1) one set of contacts (4 and 5) closes the circuit to the slow-release relay K3, which in turn energizes the transmit relay K1; (2) the other set of contacts switches the tone oscillator line from the pentode section to the triode section. The transmitter is now operating, with the tone modulation taken from the triode section of the tone oscillator.

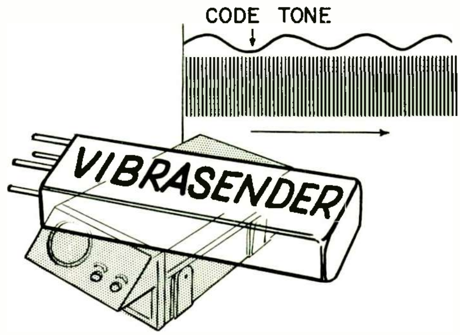
When the operator releases his push-to-talk button, squelch-tail eliminator relay K2 opens. The circuit through the coil of the slow-release relay, K3, is also opened, but the relay contacts remain closed for 120 milliseconds, during which time the transmitter remains on the air.

With the release of relay K2, the tone modulation of the carrier was switched from the triode section of the oscillator to the pentode section by the second pair of K2 contacts. The opposite phase of the tone signal from the pentode section now opposes the vibration of the reed in the vibrasponder circuit of the receiver, causing a sharp damping of its movement. The reed contacts no longer complete the vibrasponder circuit and the receiver squelch closes. By this time the slow release K3 has dropped out, releasing the transmit-receive relay and switching the system to receive. This phase change of the tone modulation quickly damps the vibrasponder reed in the receiver, thus making it possible to use a short delay time when releasing the transmit-receive relay.

In the Private Line receiver circuit of figure 4, high noise levels could cause the squelch to open under adverse conditions. A slightly different arrangement, figure 7, is possible in the driving circuit for the vibrasponder; two coupling circuits have been provided from the discriminator to the low-pass amplifier.

The coupling circuit through R1 and C1 allows the lower audio frequencies to pass, but provides high attenuation to the upper voice and higher frequencies. The more direct capacitance coupling (C2) to the grid of the amplifier introduces a certain amount of high-frequency noise energy, present at the discriminator output without a signal. Both the low-frequency noise energy and the high-frequency signal are amplified in this stage, both reaching the input of the following stage, a cathode-follower type of vibrasponder driver.

This stage is a clipper-limiter, and nearly all input signals drive the stage to plate current cutoff and saturation. Thus there is a maximum amount of signal (noise) power in the output at all times, and this does not vary. With both high and low frequency noise applied, the output is divided between the high and low frequency noise. There is not enough low-



The Vibrasender Insures that the Correct Coding Tone Modulates the Transmitter and Reaches the Receiver.

frequency energy to fully drive the reed and open the squelch.

As soon as a carrier enters the receiver, however, the noise quieting effect of the IF limiters reduces the high-frequency noise at the discriminator output. The only signal reaching the low-pass amplifier, then, is the tone signal. All the output power of the vibrasponder driver stage is now concentrated at the tone frequency, the reed is energized, and the squelch opens.

There is another feature of this circuit (figure 7) which makes it immune to noise. By placing the vibrasponder coil in parallel with a low impedance, the coil damps the reed and undesirable noise energy cannot open the squelch. Consider for a moment the action if a high impedance instead of a low resistance were in parallel with the coil.

Noise energy reaching the coil sets the reed in motion, only to have successive noise pulses cause damping currents in the coil. The net result? The squelch remains closed. Strong, low-frequency noise pulses, however, occasionally drive the stage to cutoff and, due to the time period of this low-frequency pulse, the stage is held at cutoff for some time.

The reed has already been driven by the strong pulse and is now free to vibrate without interruption; the tube is at cutoff and noise energy at the grid does not reach the cathode. The reed continues to vibrate and opens the squelch. The one damping effect upon the reed is the current through the coil, and this depends upon the Q of the coil. The high resistance in parallel with the coil allows a high Q and there is but little damping.

Now let's see what happens when the vibrasponder coil is in parallel with a low resistance, as in figure 7. Again the strong, low-frequency pulses bias the tube to cutoff and drive the reed. The Q of the circuit now depends on the low resistance of the cathode resistor, and the effective Q is considerably lower.

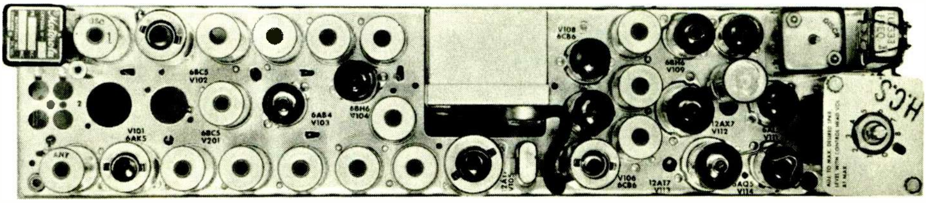
As a result, the coil currents decay quickly and the reed is damped, before the squelch has had time to open.

This arrangement, being relatively free from the triggering effects of noise pulses, will not open the squelch unless the correct tone is applied.

Private Line Systems

Various types of Private Line radio operation will be found in use. One system employs Private Line radio operation only from the control dispatcher at the base station to the mobile units. With this system the mobiles hear only those calls originating at the base; there is no mobile-to-mobile communication so long as the mobile receivers are in Private Line radio position. If the switches at the mobile units are placed in the "Private Line OFF" position, however, the operators can hear all the transmissions on their frequency.

Another type of Private Line radio operation has coding tones



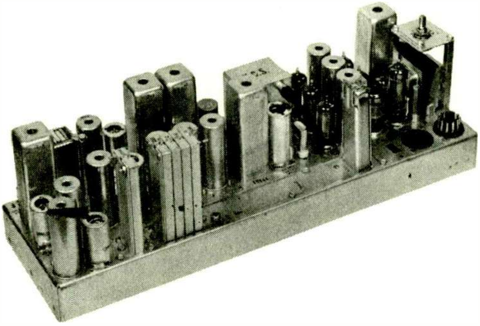
The Vibrasponder is Seen at the Upper Right Corner of this Private Line Receiver.

at all units, giving the entire system freedom from all signals except those of its own net. By means of a switch, any operator may disable his squelch and listen to all messages on the channel. There is no squelch system to silence the receiver between messages, however, and there is considerable FM noise in the speaker.

Squelch-tail elimination may or may not be used; it depends upon the particular needs of each system. The squelch-tail eliminator circuit is often incorporated in the base transmitter only, so that the mobile receivers do not hear the squelch-tail noise. Without the squelch-tail eliminator included in the mobile transmitters, the base receiver is subject to squelch tail.

Disabling The Private Line Squelch

Let us return briefly to figure 5, which shows a Private Line base station designed to operate on the 450-mc band. It is sometimes desirable for the operator to disable his squelch circuit to monitor the band or to check on the operation of his receiver. This operation can be performed by closing a switch on the remote console. The resulting current in the control line produces a voltage drop across relay K1 (shown in the remote control chassis). This current is not sufficient to operate the relay, but the voltage drop across the relay coil, when ap-



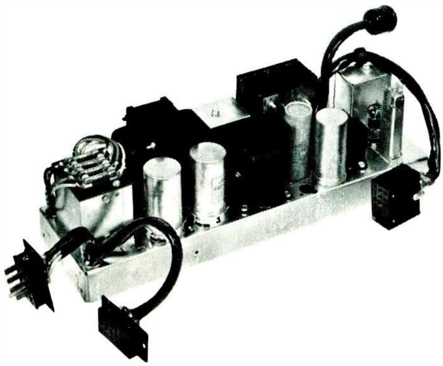
The Vibrasponder is Seen at the Right Front Section of this 450-MC Receiver.

plied to the cathode of the squelch control tube in the receiver, stops that tube from conducting and, in turn, opens the squelch.

This circuit enables the operator to disable the receiver squelch from his remote control console. The Private Line radio disabling system of figure 5 has one side of the control line grounded. This unbalance in the line can be a source of hum. An alternate circuit for disabling the base station Private Line squelch is shown (the dotted lines) immediately below the remote control chassis.

A second relay (K4) is connected in series with control relay K1. (Jumper JU3 is removed.) In parallel with K4, we find a diode rectifier. This rectifier acts like a bypass to K4 for the DC current (approximately 10 ma) which operates K1.

When the operator at the remote console closes his Private Line switch, a DC current is again established in the control line, but it is in the opposite direction. This current, only 4 ma, cannot operate relay K1; it must pass through the coil of relay K2, however, for the crystal offers a high impedance to current in this direction. The relay now closes, and disables the squelch control tube by opening its cathode circuit.



The Vibrasender and Oscillator, Which Controls the Tone Modulation of the Transmitter, is Usually Located on the Power Supply Chassis.

The ground can be removed from one side of the control line in this alternate circuit, and the line may now be balanced for minimum hum pickup. The operator may then monitor the channel for a period of time, but in the absence of transmissions or signals from other transmitters, the receiver becomes very noisy. It is evident that a system incorporating both Private Line radio squelch and normal squelch (carrier squelch) would be desirable. This combination is used in the Motorola "dual squelch" Private Line system.

Dual Squelch

The simplified circuit of figure 8 shows the squelch section of a Private Line receiver which incorporates both a tone-operated squelch and a carrier-operated squelch. A switch on the operator's control head enables selection of either private line squelch operation or normal squelch operation. With the switch in the PRIVATE LINE position, the carrier squelch section is disabled; the only operative squelch circuit now is the Private Line tone circuit, and only these signals having the proper coding tone will be heard. With the switch in the off position, however, all transmissions on the channel will be heard; the carrier-operated squelch, now active, silences the receiver between transmissions.

The operation of the circuit with the operator's switch in the PRIVATE LINE position is the same as if the carrier circuitry were not included. The cathode of the Private Line DC amplifier is grounded, making the Private Line squelch independent of the carrier squelch section. The Private Line DC amplifier tube will be conductive or nonconductive, depending upon the bias on its grid. This, in turn, is determined by the activity of the vibrasponder reed. If the coding tone is not applied, the reed does not vibrate and, because there is no large negative bias applied to the grid, the DC control tube conducts, thereby squelching the receiver.

When the correct tone is received, the reed vibrates and applies the -17 volt bias from the limited grid to the grid circuit of the control tube. This biases the control tube beyond cutoff, making it nonconductive and opening the squelch.

When the PRIVATE LINE switch is placed in the "off" position, the Private Line DC amplifier and the carrier squelch DC amplifier are placed in series as far as their plate currents are concerned. If either of these tubes should now become nonconductive the receiver squelch will open.

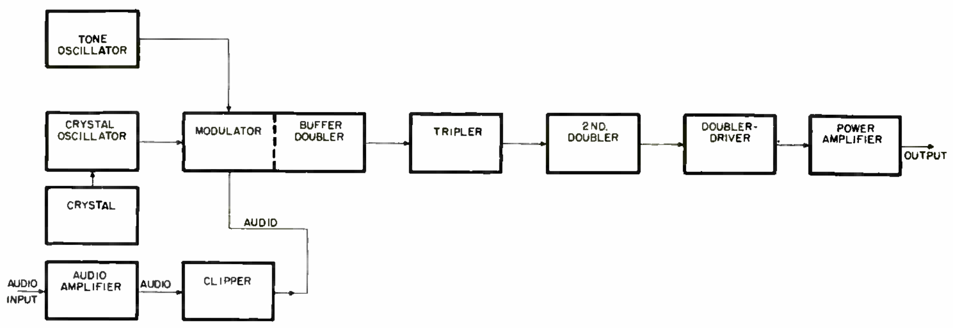
The operation of the carrier squelch section is the same as that of the noise-compensated squelch circuit previously explained. Noise from the discriminator, in the absence of a carrier, is applied to the noise amplifier. The amplifier output is then rectified by the noise rectifier and this positive DC voltage is applied to the grid of the DC control tube. This positive voltage opposes the negative voltage from the grid of the limiter, and the bias on the DC amplifier stage approaches zero, allowing the DC amplifier tube to conduct. The Private Line DC amplifier of figure 8 is also conductive in the absence of the Private Line tone and the audio tube is biased beyond cutoff. The receiver is squelched.

As soon as a carrier is received, the action of the limiters reduces the noise input to the noise amplifier and the positive output voltage from the noise rectifier is also greatly reduced, perhaps to zero. As a result, the limiter grid voltage makes the grid of the carrier squelch DC amplifier, highly negative and the tube is at cutoff. With the carrier DC amplifier at cutoff there can be no current through the private line DC amplifier, and the squelch is open. Any signals coming into the receiver will now be heard. So long as the carrier is being received, the carrier squelch DC amplifier is at cutoff and keeps the squelch open.

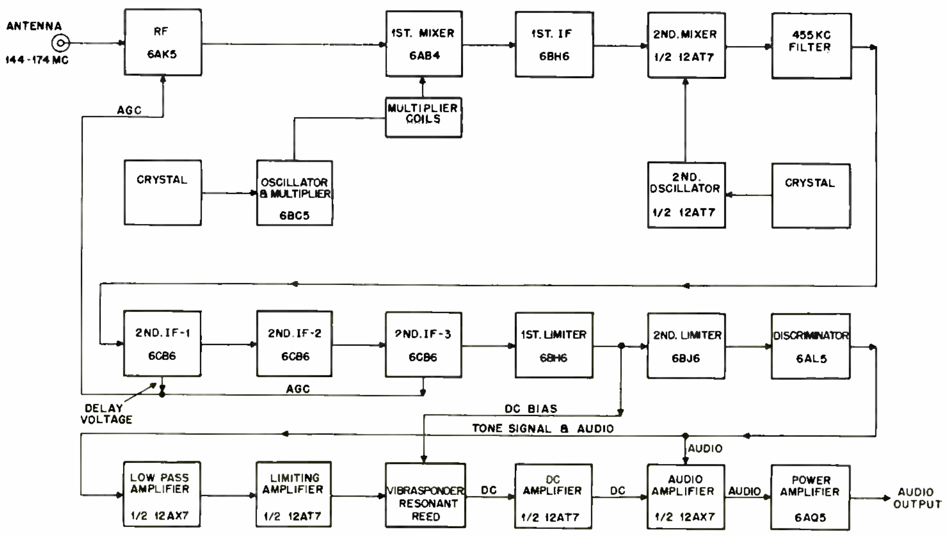
The operator of dual-squelch equipment may listen either (1) to signals of his own system, or (2) to any signals on the channel. (This is made possible by the PRIVATE LINE switch.) In either instance, one of the squelch circuits is effective, silencing the receiver between transmissions.

STUDENT NOTES

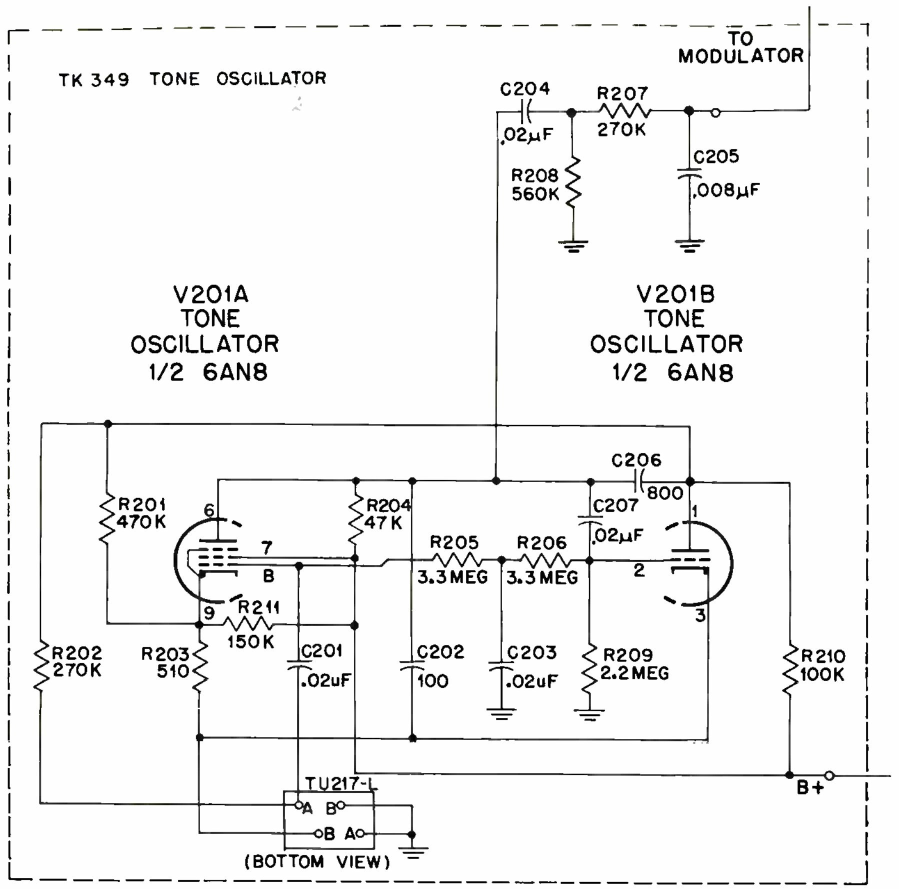
STUDENT NOTES



HIGH-BAND "PRIVATE LINE" TRANSMITTER
FIGURE 1



HIGH-BAND "PRIVATE LINE" RECEIVER
FIGURE 2



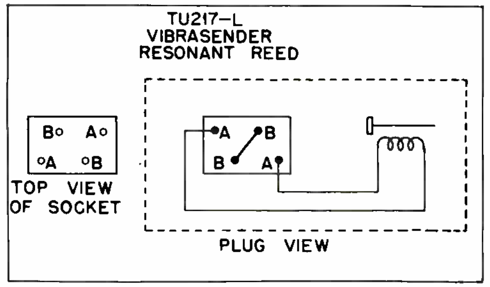
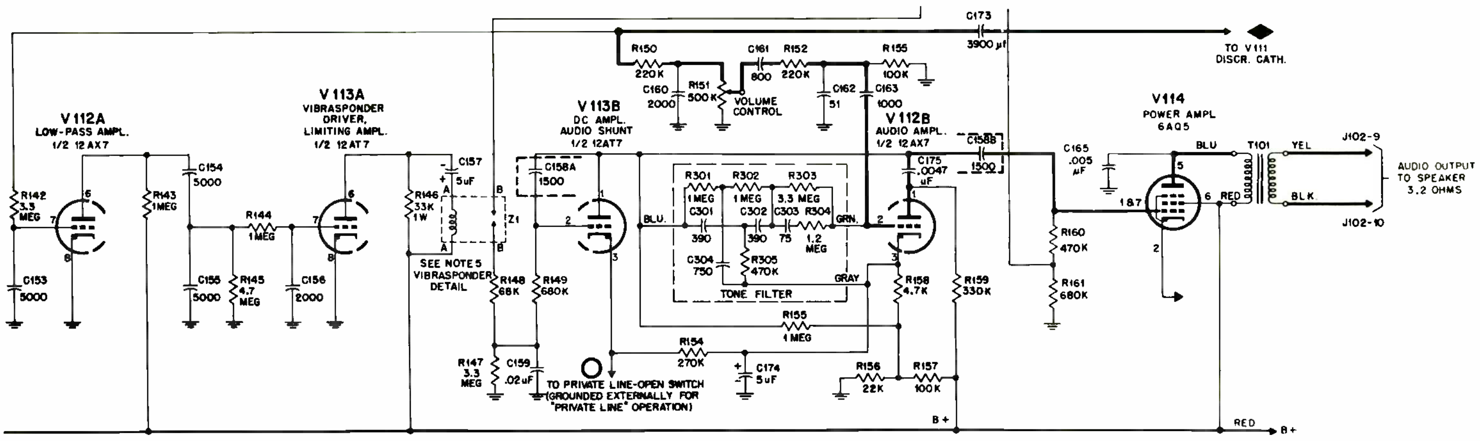


FIGURE 3



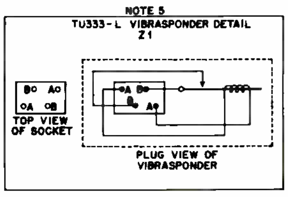


FIGURE 4

STUDENT NOTES

STUDENT NOTES

CONDITIONS

1. 117 VOLT, 60CPS AC LINE CONNECTED TO FUSE BLOCK.
2. CONTROL LINE CONNECTED TO TERMS. 7 & 8, BOTTOM ROW REMOTE CONTROL CHASSIS.
3. PUSH-TO-TALK BUTTON DEPRESSED (AT REMOTE CONTROL CONSOLE)

RESULTS

1. REMOTE CONTROL CHASSIS TRANSMIT-RECEIVE RELAY ENERGIZED.
2. SQUELCH TAIL ELIMINATOR RELAYS ENERGIZED.
3. POWER SUPPLY TRANSMIT-RECEIVE RELAY ENERGIZED.
4. RED LIGHT ON CABINET ENERGIZED. (INDOOR MODEL ONLY).
5. HIGH B+ APPLIED TO FINAL RF AMPLIFIER.
6. ANTENNA RELAY ENERGIZED.
7. TONE-MODULATED CARRIER ON AIR.

RELEASE OF PUSH-TO-TALK BUTTON

1. SQUELCH TAIL ELIMINATOR RELAY K3 DE-ENERGIZES, GROUNDING TONE OUTPUT IMMEDIATELY.
2. CAPACITOR C2 DISCHARGES THROUGH RELAY K2 AND DELAY ADJUSTMENT NETWORK.
3. K2 REMAINS ENERGIZED FOR THE TIME CONSTANT PERIOD.
4. TRANSMIT-RECEIVE RELAY K1 REMAINS ENERGIZED FOR THE TIME CONSTANT PERIOD.
5. UNMODULATED CARRIER REMAINS ON THE AIR FOR THE TIME CONSTANT PERIOD.

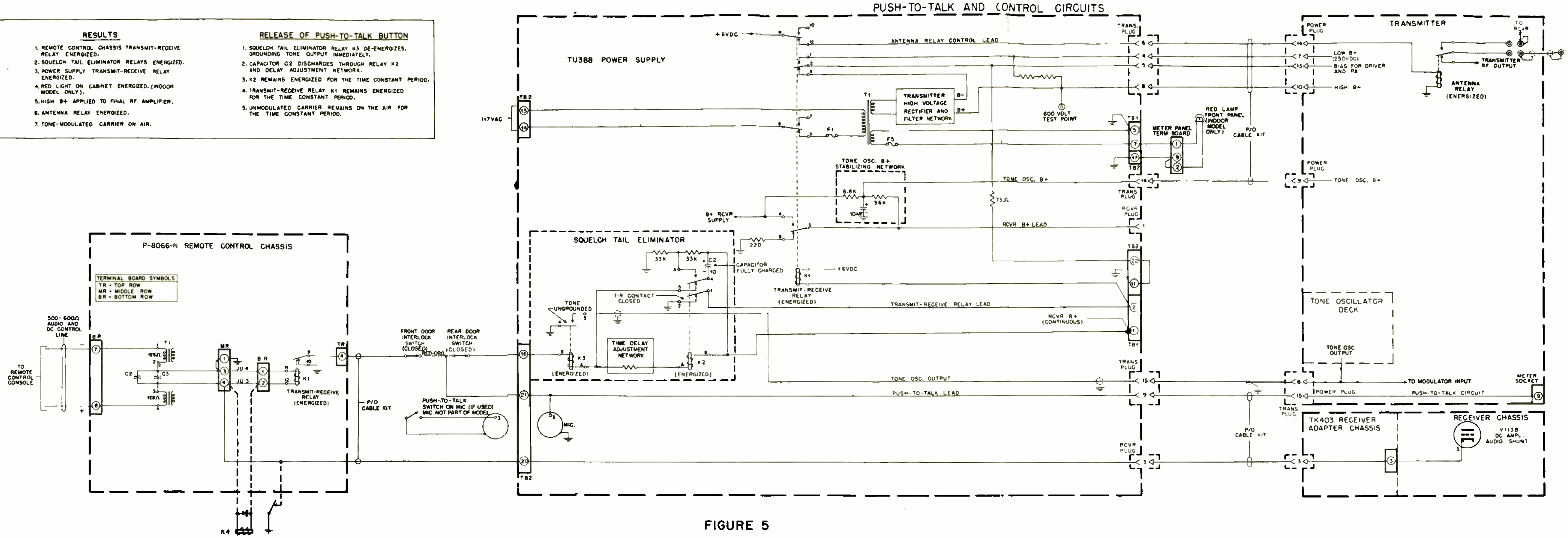


FIGURE 5

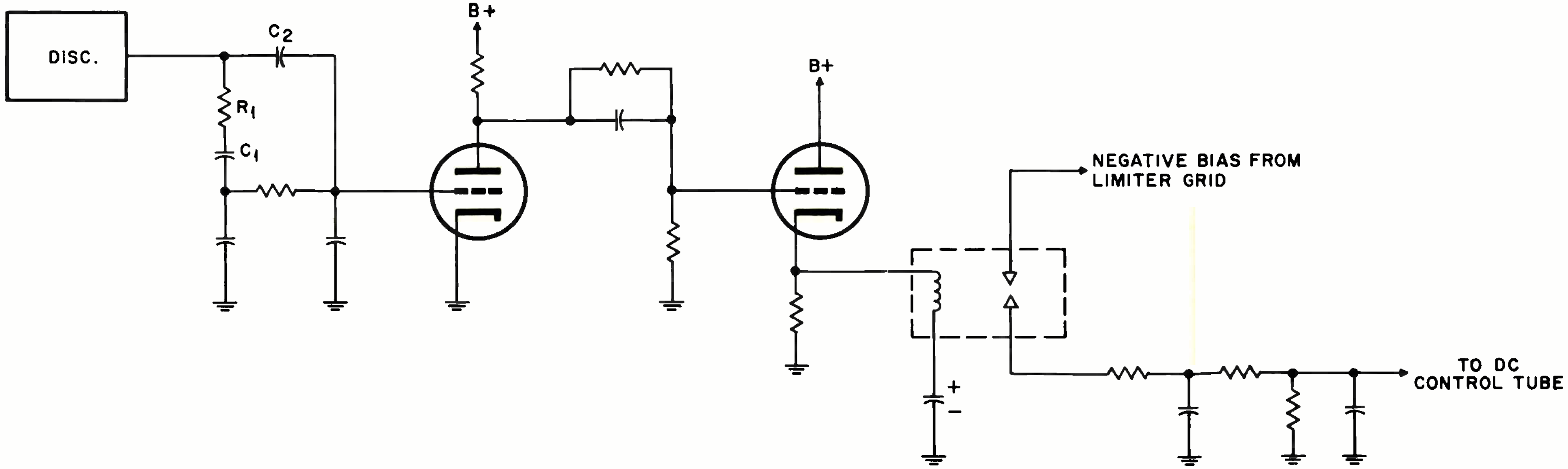
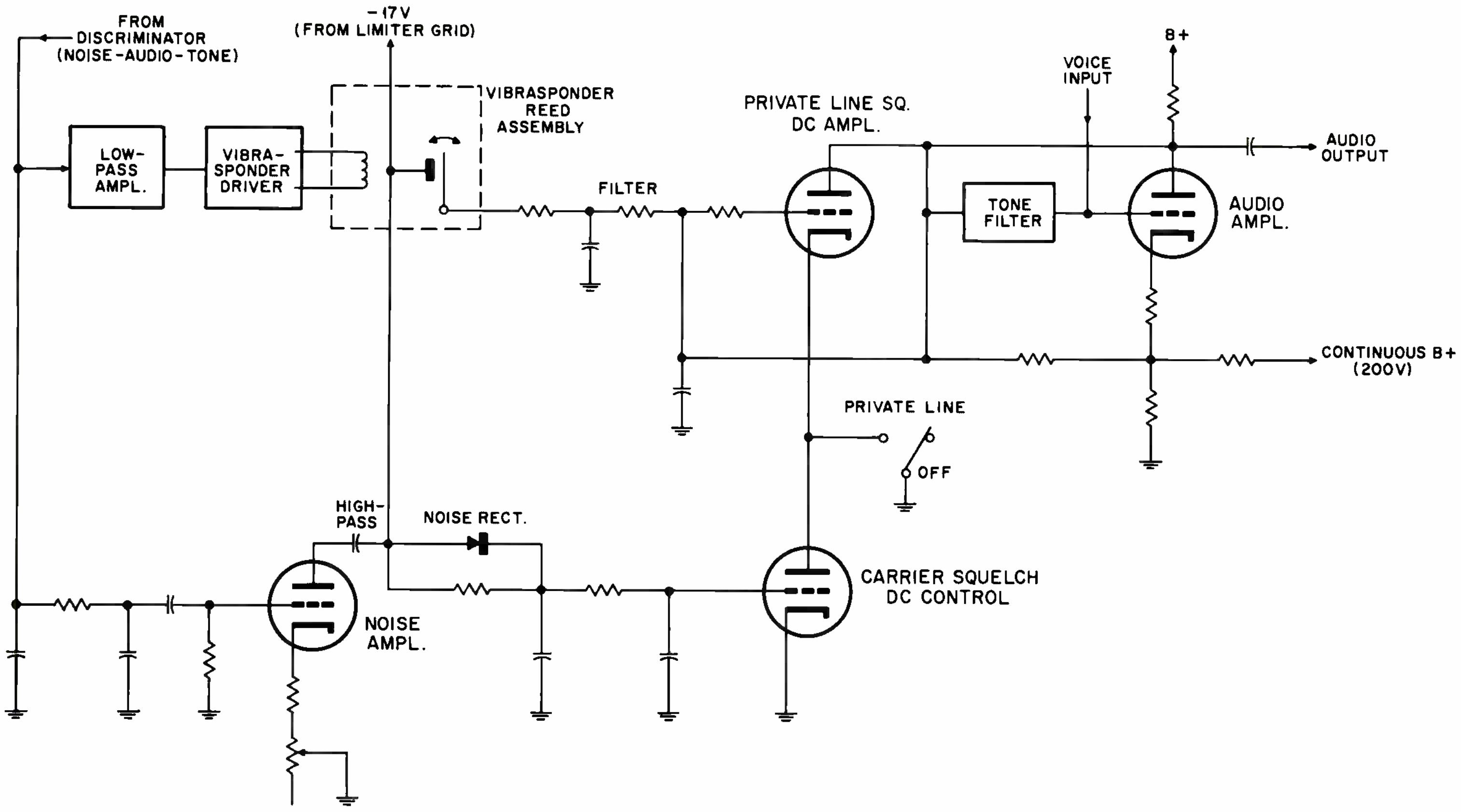


FIGURE 7



DUAL SQUELCH
FIGURE 8

STUDENT NOTES

STUDENT NOTES

STUDENT NOTES

FAST-ACTING SQUELCH
CONTROL CIRCUIT DIAGRAM

SEQUENCE OF OPERATIONS

CONDITIONS

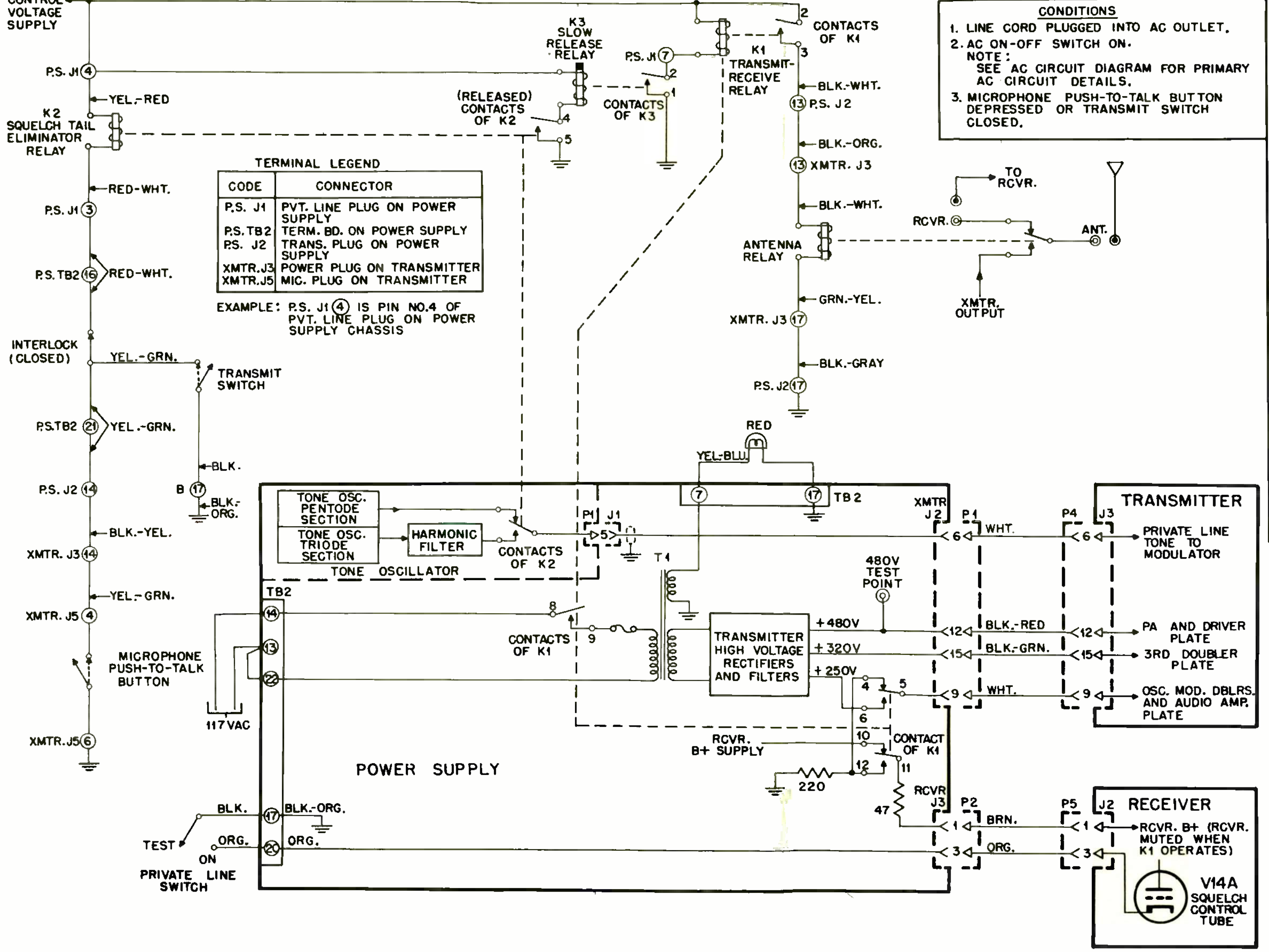
1. LINE CORD PLUGGED INTO AC OUTLET.
2. AC ON-OFF SWITCH ON.
   NOTE:
   SEE AC CIRCUIT DIAGRAM FOR PRIMARY AC CIRCUIT DETAILS.
3. MICROPHONE PUSH-TO-TALK BUTTON DEPRESSED OR TRANSMIT SWITCH CLOSED.

RESULTS

1. SQUELCH TAIL ELIMINATOR RELAY K2 IS ENERGIZED.
2. CONTACTS OF K2 OPERATE SLOW RELEASE RELAY K3.
3. CONTACTS OF K3 OPERATE TRANSMIT-RECEIVE RELAY K1.
4. CONTACTS OF K1 OPERATE ANTENNA RELAY.
5. CONTACTS OF K1 APPLY 117VAC TO TRANSMITTER HIGH VOLTAGE POWER SUPPLY.
6. CONTACTS OF K2 CONNECT TRIODE TONE OSCILLATOR OUTPUT TO TRANSMITTER MODULATOR.
7. TONE-MODULATED CARRIER GOES ON THE AIR.
8. RED LIGHT ON FRONT PANEL GOES ON.

RELEASE OF PUSH-TO-TALK BUTTON

1. SQUELCH TAIL ELIMINATOR RELAY K2 CONTACTS OPEN IMMEDIATELY.
2. CONTACTS OF K2 TRANSFER MODULATOR TONE INPUT FROM TRIODE SECTION TO PENTODE SECTION OF TONE OSCILLATOR.
3. PHASE-SHIFTED PENTODE OUTPUT DAMPS VIBRATIONS OF RESONANT REED AT RECEIVER.
4. AFTER 120 MILLISECONDS SLOW RELEASE RELAY BREAKS TRANSMIT-RECEIVE RELAY CIRCUIT, TAKING CARRIER OFF THE AIR.
5. RED LIGHT GOES OUT. ANTENNA RELAY TRANSFERS ANTENNA TO RECEIVER.



TERMINAL LEGEND

CODE	CONNECTOR
P.S. J1	PVT. LINE PLUG ON POWER SUPPLY
P.S. TB2	TERM. BD. ON POWER SUPPLY
P.S. J2	TRANS. PLUG ON POWER SUPPLY
XMTR. J3	POWER PLUG ON TRANSMITTER
XMTR. J5	MIC. PLUG ON TRANSMITTER

EXAMPLE: P.S. J1 (4) IS PIN NO.4 OF PVT. LINE PLUG ON POWER SUPPLY CHASSIS

FIGURE 6

national

MOTOROLA

RADIO COMMUNICATIONS

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