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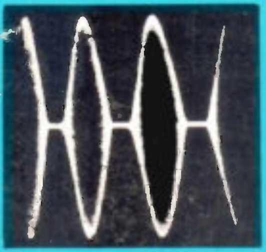
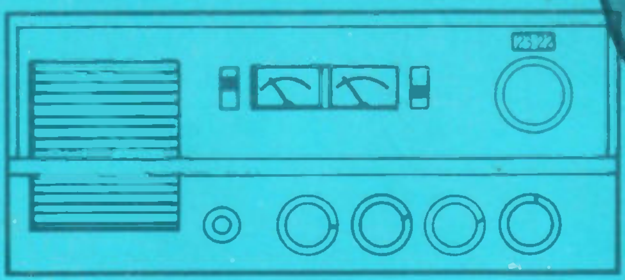
by

LEO G. SANDS





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Preface

The growth of Citizens-band radio since 1958 has been tremendous. The number of CB units in operation have increased to several million, resulting in more demand for maintenance services. Thus, the opportunity for radio and tv service shops to expand into CB service has never been better. Although there are many radio and tv service technicians who already have the Second-Class Radiotelephone Operator's license needed to perform or supervise complete maintenance of CB radio units, no license is needed for a great many CB-radio service calls. The technically inclined nonprofessional need have no qualms on this score.

This book was written to furnish a comprehensive guide to CB-radio servicing—to aid not only the professional service technician, but also the CB-radio user who wishes to get maximum performance from his set. A troubleshooting chart, covering most of the common CB-unit troubles, has been included, in addition to numerous other diagrams and tables describing CB-radio operation. It is felt that if this guide is used in conjunction with the details furnished in manufacturers' manuals, complete CB-radio maintenance can be accomplished quickly and easily.

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CHAPTER 1

Citizens Band Radio Equipment

A Citizens band radio, or CB set, is a radio transceiver, which is capable of operation on one or more of the 23 channel frequencies in the so-called Citizens band between 26.965 and 27.255 megahertz (MHz). It is used for two-way radiotelephone communications on a simplex basis (transmission and reception take place sequentially, not simultaneously). It employs amplitude-modulation (a-m) or single-sideband (ssb) emission, and transmitter power is limited to 4 watts output on a-m and 12 watts peak envelope power (pep) on ssb. A Class-D radio-station license is required in order to use the transmitter; however, no operator license is required.

DEFINITIONS AND RULES

There are other classes of equipment which are also licensed in the Citizens Radio Service. These include Class-C radio-control transmitters, which operate in the same band, and Class-A stations which operate in the 460- to 470-MHz band. This book covers only equipment intended to be licensed as a Class-D Citizens Radio station.

All Class-D Radio transceivers are classified in the license as mobile units, whether used at fixed locations, on-board conveyances, or carried from place to place.

The transmitters of all Class-D Citizens radio units are crystal controlled as required by FCC regulations. Although the receivers of some early CB transceivers are tunable across the band, the receivers of nearly all modern CB transceivers are crystal controlled. Class-D

CB transmitters that are first sold or licensed after November 22, 1974 must be "type accepted" by the FCC. Transmitters that have not been FCC type accepted may not be operated after November 22, 1978.

Type acceptance of a transmitter may be applied for by its manufacturer or by an independent testing laboratory in behalf of the manufacturer. To obtain FCC type acceptance, the transmitter is subjected to comprehensive tests, and the results of the tests are submitted to the FCC for consideration. After a transmitter has been assigned an FCC type acceptance number, any change in the design not made with FCC permission, or any modifications made after manufacture, automatically nullify the type acceptance. A service technician who has modified a transmitter may apply for type acceptance of that particular transmitter. How to conduct type acceptance tests and how to apply for FCC type acceptance are explained in the *FCC Type Acceptance Manual* which is available from *CB Magazine,* 531 North Ann Arbor, Oklahoma City, OK 73127.

Some CB sets are designed for operation only from a 120-volt, 60-hertz (Hz) source. When used on conveyances, an external dc power pack is required, or an external dc-to-ac inverter is employed to convert available dc to ac.

Most CB sets now on the market are designed to operate from 12 volts dc (or from 120 volts ac through the use of an external power supply), although some are designed to operate from either 12 volts dc or 115 volts ac.

Both a-m and combination a-m/ssb Class-D CB transceivers are available, as are ssb-only transceivers. Among the basic types of class-D CB equipment that the technician might be called upon to service are the following:

1. Single-channel, fixed-tuned a-m transmitter-receiver.
2. Single-channel, fixed-tuned a-m transmitter, tunable receiver.
3. Two-channel, fixed-tuned ssb transmitter-receiver.
4. Multichannel, fixed-tuned a-m transmitter-receiver.
5. Multichannel, fixed-tuned a-m transmitter, tunable receiver.
6. 23-channel, fixed-tuned a-m transmitter-receiver.
7. 23-channel, fixed-tuned a-m/ssb transmitter-receiver.
8. 23-channel, fixed-tuned ssb-only transmitter-receiver.
9. 23-channel, fixed-tuned a-m (or a-m/ssb) transmitter.
10. Tunable a-m (or a-m/ssb) receiver.

Examples of various types of sets are shown in Figs. 1-1 and 1-2. There are a great many more makes and models on the market than those shown. Although many Class-D CB transceivers are manufactured in the United States, many are also manufactured outside of the United States to FCC technical standards. Some are manufactured to meet both FCC technical standards and the technical standards of the

Fig. 1-1. Tram a-m/ssb mobile unit.

telecommunications administrations in Germany, Italy, Jamaica, and some South American nations where operation of CB transceivers is permitted.

Fig. 1-2. Cobra base station.

Base Station

A base station (licensed as a mobile unit) is a transmitter-receiver installed at a fixed location and used for communicating with mobile and portable stations as well as other base stations. A base station is generally connected to an outside antenna. For short-range communication (a mile or so) an indoor antenna can be used.

Fixed Station

A fixed station is one that is used only for communicating with other stations at fixed locations. Even though it is at a fixed location, a station which is used to communicate with mobile units as well as other stations at fixed locations is classed as a base station.

Mobile Station

While all Class-D CB stations are classed as mobile units in the station license, the trade refers to mobile units as mobile or transportable stations. A mobile station may be either temporarily or permanently installed in a vehicle.

Portable Stations

A portable station may be a hand-held walkie-talkie such as the one shown in Fig. 1-3. Walkie-talkies operated as low-power communications devices under Part 15 of the FCC Rules and Regulations need not be licensed. However, when walkie-talkies are used for communicating with licensed Class-D stations, they must be licensed and must meet the technical requirements of Part 95 of the FCC rules.

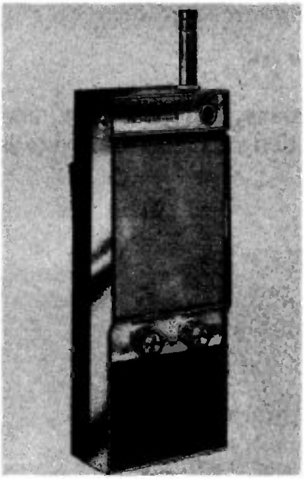


Fig. 1-3. Typical CB walkie-talkie.

TECHNICAL AND OPERATIONAL DATA

Class-D CB transmitters may employ a-m (A3) or ssb (A3a) types of modulation. Power output is limited to 4 watts on a-m and 12 watts pep on ssb. Transmitter frequency stability must be 0.005% or better. Highest permitted modulation frequency is 3000 Hz. Antenna elevation is limited as defined in FCC Rules and Regulations, Part 95.

A Class-D CB transmitter may not be remote controlled, except through wires when the remote control point is on the same premises. CB transmissions may not be rebroadcast over a public-address system. A CB station may be patched into a telephone line. Class-D CB stations are not authorized to be used for long-distance skip communication; however, communication between stations within 150 miles of each other is permitted.

Communicating range under these restrictions normally is limited to about 1 mile between two fixed stations equipped with indoor antennas. When an outdoor antenna is used at both fixed stations, distances of 30 miles can sometimes be spanned. The range of base-to-mobile communications depends on the effective elevation of the base-station antenna and the elevation of the ground where the mobile unit is operating, as well as terrain conditions between the stations. Range is also limited by the noise conditions at both locations.

The purchaser of a CB system should not expect to enjoy the same range and relative freedom from noise and interference from other stations as users of higher-powered commercial fm mobile equipment. Base-to-mobile range of 5 miles may be maximum in many cases. Under some (exceptional) conditions, a 10- to 20-mile range is enjoyed.

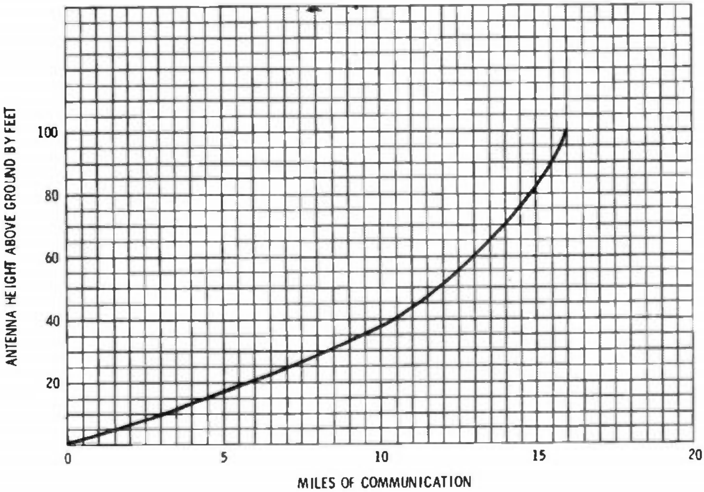
The graphs shown in Fig. 1-4 indicate the calculated ranges to be anticipated under various conditions. While a receiver may be sensitive to signals of less than 1 microvolt under shop bench-test conditions, in actual use it may be such that a 15-microvolt signal is required for useful communications. The personal CB user will often tolerate reception conditions which are totally unsatisfactory to the business user of CB radio.

Power Output

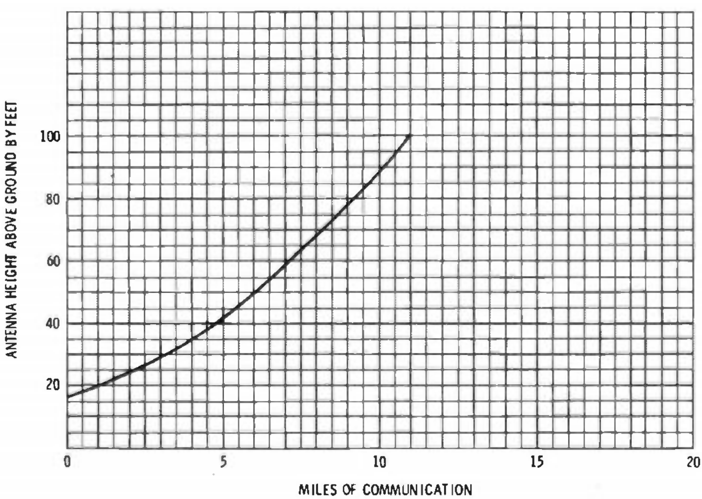
The power output of an a-m transmitter rises 50% above the unmodulated carrier level when it is 100% modulated by a sine wave. Two sidebands are generated, each containing 16.6% of the total radiated power. If the carrier power is 3 watts, for example, the total radiated power is 4.5 watts of which 0.75 watt is contained in each sideband. Since only one sideband is required to convey the information, the actual communications efficiency of an a-m transmitter is only 15% when power input is 5 watts and total radiated power output is 4.5 watts.

Although spec sheets often state that an a-m transmitter has a 100% modulation rating, modulation percentage varies widely during voice transmission and seldom reaches 100%. Since the effectiveness of an a-m signal increases with modulation percentage, some transmitters contain circuitry that increases the average modulation level. More audio gain is provided than is actually necessary, and a form of *automatic gain control* (agc) is employed to reduce gain, when input level rises, to prevent overmodulation. The result is greater "talk power." When a person speaks softly into a microphone, high audio gain increases the percentage of modulation. When a person speaks loudly into a microphone, audio gain is automatically reduced.

Overmodulation of an a-m transmitter is unlawful since harmful interference can result. When amplitude modulation exceeds 100%,



(A) 2-microvolt signal.



(B) 15-microvolt signal.

Fig. 1-4. Typical range using unity-gain antenna.

the radiated signal is no longer symmetrical and splatter can cause it to interfere with communications on adjacent channels and, possibly, on all channels.

The power output of an ssb transmitter is rated in terms of peak envelope power (pep). Since the carrier is suppressed, power output is almost zero when an ssb transmitter is not modulated. When modulated, nearly all of the power is contained in a single sideband, either the upper sideband (usb) or the lower sideband (lsb), depending upon the setting of the mode selector switch. Under current FCC rules, the pep output of an ssb Class-D CB transceiver may be as high as 12 watts.

Most ssb transceivers can also be operated in the compatible a-m mode to enable communication with a-m transceivers. When set in the a-m mode, one sideband (usually the usb), plus the carrier, is radiated. Whereas a suppressed-carrier signal cannot be demodulated by an a-m receiver, a compatible a-m signal can, because the carrier is present.

Demodulation of a suppressed-carrier ssb signal requires that the missing carrier be restored at the receiver. This is done with a beat-frequency oscillator (bfo) which, when heterodyned with the ssb signal, converts the ssb signal into an a-m signal.

Band Occupancy

The modulating frequency is limited to 3000 Hz by the FCC in order to limit band occupancy. When a double-sideband (dsb) a-m transmitter is modulated, the carrier and two sidebands are transmitted. The width of the sidebands increases with modulating frequency. When the transmitter is modulated by a voice signal containing frequencies up to 3000 Hz, each sideband is 3 kHz wide and the band occupancy is 6 kHz.

The band occupancy of an ssb signal, on the other hand, is half that of an a-m signal. When an ssb transmitter is modulated by a voice signal containing frequencies up to 3000 Hz, the one transmitted sideband is 3 kHz wide. Therefore, the band occupancy is only 3 kHz.

In addition to the ten basic types of CB equipment listed previously, there are some transceivers in existence which transmit a double-sideband, suppressed-carrier a-m signal. Since both sidebands are transmitted, the band occupancy is the same as that of a conventional a-m transmitter. But, because the carrier is suppressed, the sidebands contain more power. Demodulation of this type of signal requires a bfo in the receiver to restore the missing carrier.

WHO CAN SERVICE CB SETS?

The FCC has no jurisdiction over radio receivers, except when they radiate radio signals (generally from a local oscillator) in excess of limits specified in Part 15 of its rules. The commission does control the use of radio transmitters of all types and requires a station license for operation of transmitters, except when power is under the values specified in Part 15.

A First-Class or Second-Class Radiotelephone Operator's license is required by persons or supervisors of persons who make any repairs or adjustments to a CB transmitter. An unlicensed person can make such repairs or adjustments, but a licensed operator must check the transmitter or supervise the checking before the transmitter is put on the air.

No operator license is required to perform the following in connection with CB sets, even when they are connected to a radiating antenna.

1. Measure transmitter frequency.
2. Measure modulation level.
3. Replace tubes or vibrator.
4. Realign receiver.
5. Replace certified crystals.
6. Install or replace antenna system.

An operator license is required by persons (or their supervisors) who perform any of the following:

1. Install uncertified transmitter crystals.
2. Trim transmitter oscillator frequency (in sets with crystal padder).
3. Replace components.
4. Modify transmitter circuitry.

An unlicensed person may replace crystals when the crystal manufacturer certifies that the crystals were made specifically for use in the make and model of transceiver in which they are to be installed. The transceiver manufacturer must concur with this certification. Since the inductances and capacitances of transmitter oscillator circuits affect the crystal frequency, crystals must be made for use in specific transceivers.

CUSTOMER COMPLAINTS

The most common complaints made by customers include excessive noise, inadequate range, and channel congestion. Many times this is because the purchaser of CB equipment has been oversold. It then becomes the serviceman's chore to educate the customer. Citizens Radio can be very useful if correctly installed and operated, and if it is used for its intended purpose—short-range, two-way radio communication.

Excessive Noise

Noisy reception is caused mostly by the electrical systems of motor vehicles. The noise generated by the customer's own vehicle can be suppressed. But radiation of noise generated by other nearby vehicles cannot be stopped until laws are enacted that will require all vehicles to be treated to minimize radiation of electrical interference. Noise from nearby vehicles is reduced in CB sets that are equipped with noise limiters or noise blankers, but it is not totally eliminated. Noise can be minimized by increasing the strength of the received signal so that it will override the noise. This is done by improving either the receiving system or the transmitting system of the station being received.

Electrical noise that is generated in a vehicle and that is picked up by the transmitter and associated wiring, will modulate the transmitted signal. If the signal from a mobile unit is accompanied by noise and the same noise is not heard when there is no signal (receiver fully unsquelched), this could be the cause.

Transmitting-System Improvements—The transmitting system can be improved by feeding more power into the antenna and by locating the antenna more advantageously. Transmitter power output is limited to 4 watts, which is greater than the continuous capability of most CB transmitters. Effective transmitter power output can be raised by modulating the transmitter more heavily. If the microphone is used incorrectly (too far from mouth), modulation will be low. If it is used correctly, a higher level of modulation and consequently greater apparent power output will be realized. Customers should be taught correct microphone techniques.

Low line voltage can reduce transmitter power. If the ac line voltage at the customer's installation is less than 115 volts, it can be boosted with a transformer. Low battery voltage in a car calls for replacement of a defective battery or adjustment of the voltage regulator by an auto electrician (not a radio man).

Although the height of a CB base-station antenna is limited by FCC regulations, sometimes the highest lawful location is not the best spot. Trial-and-error location techniques might be required. Also, in cases of unsatisfactory power radiation, the antenna itself may be at fault. If it does not closely match the impedance of the transmission line (coaxial cable), too much of the power is reflected back to the transmitter and is not radiated into space. The coaxial cable, if more than 50 feet long, may sap too much of the available power. Replacement with lower-loss cable will increase the effective radiated power.

Receiving-System Improvements—Noisy reception is seldom due to lack of receiver sensitivity. A typical CB receiver will pick up signals that provide a level at the receiver input of one microvolt or less; unfortunately, the noise picked up by the antenna is often greater than that. Hence, the typical CB receiver has greater sensitivity than can be effectively utilized. The trick is to improve the signal pickup of the antenna and to suppress the generation of electrical noise in the vicinity of the receiver.

In a vehicular installation, the first step is to install noise suppressors (described later). Another step is to place the antenna in the most advantageous location. In the center of the metal car top is the best place, but some customers do not want it there.

At the base station, the antenna should be located as far away as possible from sources of noise, but not so far that an excessively long coaxial cable is required. Noise generated by electric motors, aquarium thermostats, and switches should be suppressed with suitable filters.

Inadequate Range

Inadequate range is a term that is often misinterpreted. The customer may expect more range than his equipment can deliver under the circumstances peculiar to his locations and environments. Maximum attainable range may not be realized because of excessive noise which is not the fault of the equipment, or because of improper use (wrong microphone technique), less-than-optimum antenna systems, or improperly operating equipment.

High noise level when no signal is present generally indicates that the receiver is sensitive. However, if a receiver crystal is off-frequency, the receiver may not be sufficiently sensitive to on-frequency signals. By the same token, a signal from an off-frequency transmitter will not be well received by an on-frequency receiver.

Channel Congestion

Many CBers (Citizens band operators) complain about channel congestion. In populous areas, there are more CB sets in use than can be accommodated by the available channels. The some 2,000,000 CB licensees operate an estimated 6,000,000 transceivers. In addition, it is estimated that several million CB transceivers are operated unlawfully without licenses. And, to add to the channel congestion, there are millions of low-power walkie-talkies that are operated lawfully on CB channels without licenses, as permitted by FCC Rules and Regulations, Part 15.

To further aggravate the channel congestion problem, countless CBers use linear amplifiers unlawfully to increase transmitter power output to as much as several hundred watts. The service technician should be aware that his operator license can be revoked if he is found guilty of servicing, installing, or selling unlawful linear amplifiers used to increase CB transmitter output power above legal limits.

Another very serious cause of channel congestion is "skip" interference. Because of the nature of radio propagation at 27 MHz, CB stations can be heard hundreds and even thousands of miles away when skip conditions exist. Skip interference occurs when the radio signals travel upward at an angle to the ionosphere, which reflects them back to the earth at a considerable distance away from the transmission point. The author, when on the island of Jamaica in the West Indies, used a 23-channel CB walkie-talkie to evaluate the seriousness of this problem. He heard CB stations in Minnesota, North Carolina, and New Jersey more clearly than nearby Jamaican stations whose signals were inundated by the skip signals.

Those CBers who use CB radio for idle chit-chat and for a hobby are the most serious causes of CB channel congestion. They talk on and on and often refuse to get off the air even to allow someone else to transmit an emergency message.

Those customers who have bought Class-D CB radio equipment to use for business communications but are unable to get satisfactory communications on the Citizens band, should be encouraged to get licenses in the Business Radio Service and buy radio equipment for operation on channels other than CB. When both personal and business communications are required, these customers should consider switching to the Class-A Citizens band, which is within the 450- to 470-MHz land mobile band.

Sometimes, apparent congestion is caused by strong signals on an adjacent channel. Some CB sets are not selective enough to reject very strong adjacent-channel signals. Sometimes strong adjacent-channel signals will desensitize a receiver by overloading its front end or causing an increase in agc voltage.

TONE SQUELCH

The receiver can be silenced at all times, except to intercept signals from desired stations, if all stations in a system are equipped with tone squelch. Whenever a transmitter is turned on, an audio tone is transmitted which unlocks the tone-squelch decoder of all associated receivers. The tone may be at such a low frequency that it is not objectionable, or it may be filtered out at each associated receiver, as shown in Fig. 1-5. It will then be inaudible at associated receivers but will be heard at all receivers within range which do not have tone-squelch decoders. Voice is transmitted over the tone.

Tone-squelch encoder-decoders are available. Although tone squelch locks out receivers until a signal is intercepted which is modulated by a tone of appropriate frequency, tone squelch will not lock out nontone-accompanied signals while the unlocking tone is being received.

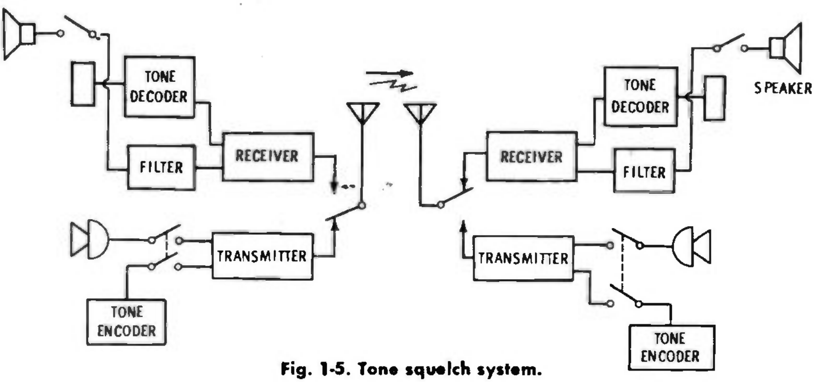


Fig. 1-5. Tone squelch system.

UNLICENSED TRANSMITTERS

No station license is required for operation of a low-power transceiver, such as the walkie-talkie shown in Fig. 1-6. These low-power units may be operated within the 27-MHz Citizens band, but not necessarily on specific channels. Licensed CB stations may not lawfully communicate with unlicensed stations except in emergencies. However, a low-power transceiver that meets CB technical standards (Part 95) can be covered by a CB station license, in which case such

Fig. 1-6. MK II walkie-talkie.

a transceiver may be used lawfully for communicating with licensed CB stations.

The operation of unlicensed transmitters within the 27-MHz Citizens band is covered by Part 15 of the FCC Rules and Regulations. Transmitter power input must be 100 milliwatts or less, and antenna length (including transmission line) must be 5 feet or less.

Under Part 15, transmitters that are operated within the 27-MHz band but without a station license are required to be bilaterally certified by the FCC and the manufacturer as meeting the applicable technical standards.

No station license is required for operation of transmitters within the 160- to 190-kHz band when they conform with Part 15 technical standards. Transmitter input power is limited to 1 watt and antenna length (including transmission line) is limited to 50 feet. This was the "first Citizens band." Although there is currently little activity on this band, it has considerable future potential. Operators using this band report point-to-point range of up to fifty miles. Since this band is only 30-kHz wide, there is room for only five a-m channels or ten ssb channels. The rules do not specify any specific channels. The only requirement is that carriers and sidebands be confined within the 160- to 190-kHz band.

CHAPTER 2

Test Equipment

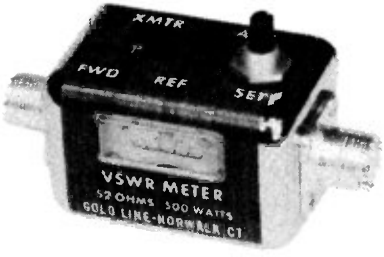
It is possible for an experienced technician to service CB sets with a minimum of tools. A volt-ohm-milliammeter (vom), a No. 47 pilot lamp, and a few hand tools will sometimes suffice. However, to do a professional job, adequate test equipment is required.

FIELD SERVICE EQUIPMENT

For field service calls, the following equipment is essential: through-line rf power meter, tube tester, vom, and frequency meter. Field servicing is generally confined to correction of those faults that only require replacement of plug-in components. If other trouble exists in the CB set, it should be taken to the shop for repair.

The through-line rf power meter (Fig. 2-1) is essential for determining whether the trouble is in the transmitter, microphone, or antenna system. A vom (Fig. 2-2) is an obvious necessity for measuring ac line voltage (or battery voltage) and continuity checking.

Several multipurpose CB checkers are on the market. The Pace P-5425 two-way radio test meter, shown in Fig. 2-3, for example, can be used to measure transmitter rf power output, check antenna-system standing-wave ratio (swr), measure amplitude-modulation percentage,

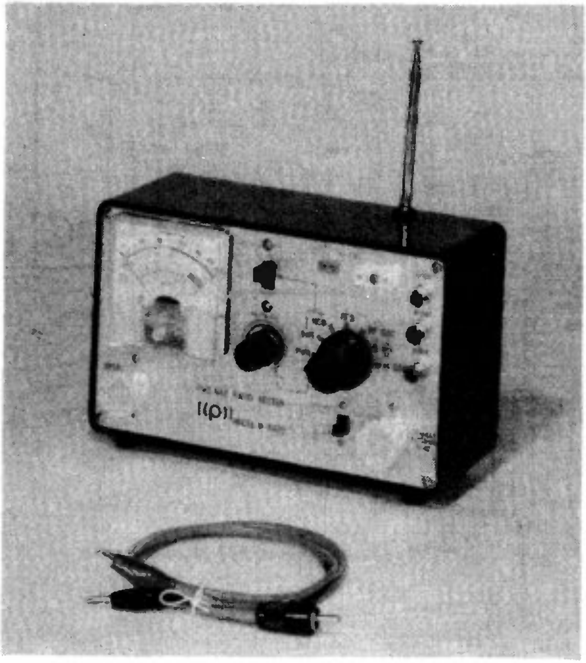


Courtesy Gold Line Connector, Inc.

Fig. 2-1. Typical swr meter for antenna and transmitter checks.

Fig. 2-2. Typical volt-ohm-milliammeter.

Courtesy Weston Instruments, Inc.



Courtesy Pace Division, Pathcom, Inc.

Fig. 2-3. Pace P- 5425 two-way radio test meter.

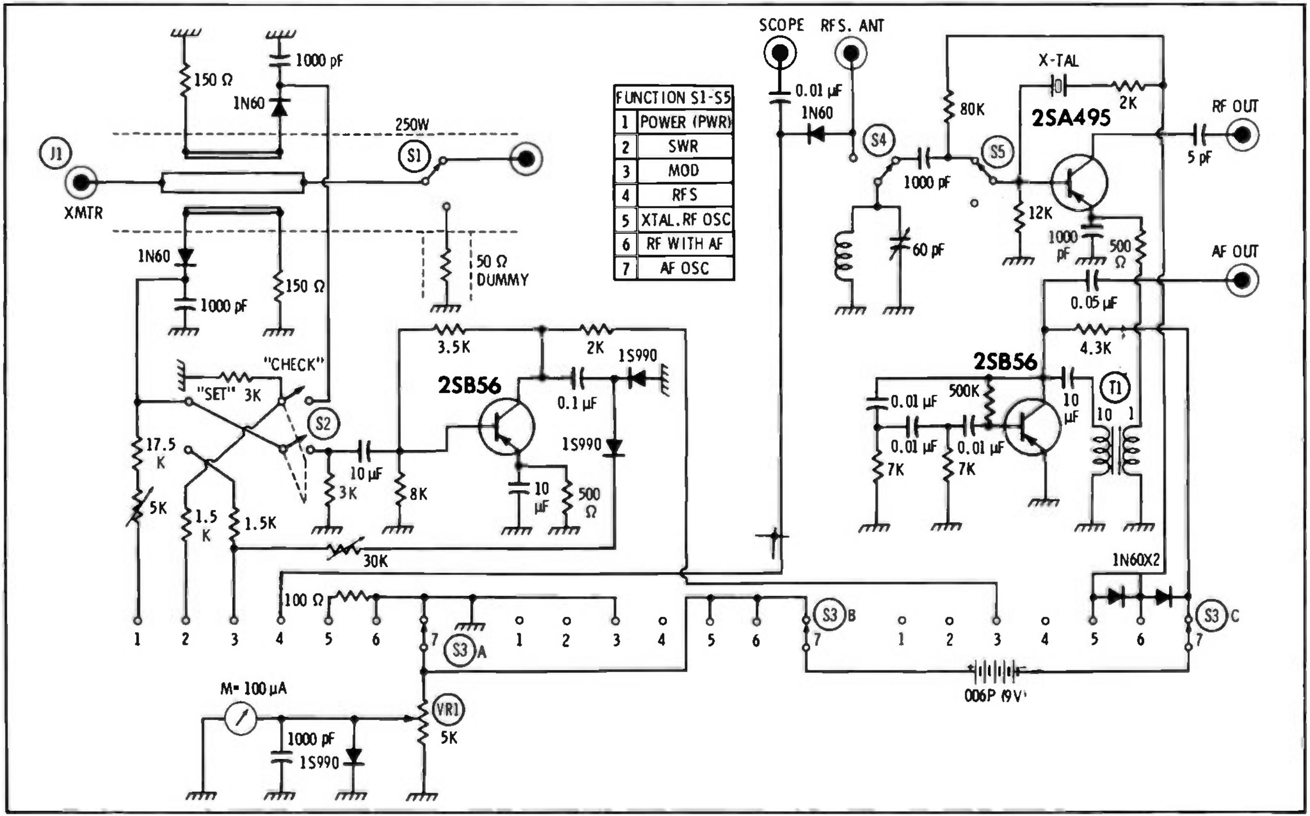


Fig. 2-4. Schematic diagram of two-way radio test meter.

measure relative field strength, check crystals, and check receiver operation. Since the Pace P-5425 has two rf power ranges, 0 to 25 watts and 0 to 250 watts, it can be used for servicing the 25- to 50-MHz commercial band for land mobile-radio equipment in addition to servicing Class-D CB transceivers.

This compact portable instrument contains a 27-MHz band crystal-controlled rf oscillator and a 1000-Hz af oscillator. The frequency of the rf oscillator is determined by a crystal that is plugged into the crystal socket on the front panel. Fig. 2-4 is a schematic diagram of the instrument. It utilizes three transistors, two as oscillators and one as an amplifier which is used when making modulation measurements. Two Type SO-239 coaxial sockets are provided for transmitter output and antenna connections. Also on the front panel are three phono jacks, two for oscillator outputs and one for connection to an external oscilloscope with which the modulation envelope can be observed.

One of the handiest field servicing devices is the Gold Line GLC-1057 dummy load, which contains a lamp that glows when rf power is present and which brightens when the transmitter is amplitude modulated.

Since the customer is responsible to the FCC for the proper operation of his transmitter and because off-frequency operation is the most common technical violation of FCC rules, an accurate frequency meter should always be available for checking transmitter frequencies. Table 2-1 lists field servicing equipment and their applications.

Table 2-1. Test Equipment for Field Servicing

Instrument	Type	Applications
RF Wattmeter	Swr meter or directional	1. Power output measurements 2. Antenna tests
Dummy Load	50-ohm with PL-259 plug.	1. For use with above when antenna not connected
Multimeter	Vom or battery-operated FET meter	1. Continuity tests 2. Battery voltage measurements
Frequency Meter	Battery-operated	1. Frequency measurements
TV Receiver	Battery-operated portable	1. Television interference checks
Walkie-Talkie	23-channel	1. Communication checks
AC Voltmeter	Expanded range, 100 to 130 volts	1. Line voltage checks
Tube Tester	Transconductance, or similar	1. Tube checks
Field-Strength Meter	27 MHz	1. Radiation checks

SHOP EQUIPMENT

The shop requires a more extensive array of test equipment, including the items listed in Table 2-2.

Dummy Antenna Load

No transmitter should be serviced when connected to a radiating antenna, because harmful interference can be caused to others. A radiating antenna should be used only when it is known that the transmitter will operate in conformity with applicable FCC technical standards and when the transmitter and operator are covered by a valid station license. All transmitter servicing in the shop should be performed only when the transmitter is terminated in a nonradiating dummy load or loaded-type rf power meter.

The simplest dummy load consists of a No. 47 pilot lamp, as shown in Fig. 2-5. A variety of these dummy loads should be available to fit every type of antenna plug required for all makes of CB sets to be serviced. The lamp serves as a load (approximately 50 ohms) and as a relative power-output and modulation indicator.

A dummy load that more accurately approximates 50 ohms is shown in Fig. 2-6. The rf power and modulation meter shown in Fig.

Table 2-2. Shop Test Equipment

Instrument	Type	Applications
Communications Monitor	Singer FM-10C or equal	1. Frequency measurements 2. Modulation measurements 3. Precision signal generator 4. Calibrator
Frequency Deviation Meter	International 2400 or equal	1. Frequency measurement 2. Precision signal generator
Rf Signal Generator	250 kHz to 30 MHz	1. Receiver alignment 2. Sensitivity measurements 3. Selectivity measurements 4. Spurious response measurements
Communications Receiver	540 kHz to 30 MHz	1. Intermediate-frequency measurements 2. Spurious emission checks 3. Transmitter checks 4. Receiver bandpass checks
CB transceiver	23-channel, a-m/ssb	1. Signal generator 2. Transmitter checks 3. Relative frequency checks
Oscilloscope	Dc to 30 MHz	1. Modulation measurements 2. Signal tracing 3. Distortion analysis

Table 2-2. Shop Test Equipment—cont

Instrument	Type	Applications
Af Signal Generator	20 to 20,000 Hz	1. Modulation checks 2. Frequency response measurements 3. Signal tracing
Rf Wattmeter	50-ohm internal load 0 to 10 watts	1. Power output measurements
Rf Wattmeter	Peak reading	1. Pep measurements
Tube Tester	Transconductance, or equal	1. Tube checking
Transistor Tester	In-circuit	1. Transistor checking
Multimeter	Vom, vtvm, FET meter, etc.	1. Voltage/current/resistance measurements 2. Trouble shooting
Dip Meter	Battery-operated portable, 100 kHz to 30 MHz	1. Antenna resonance checks 2. Tuned circuit checks 3. Relative frequency measurements
Rf Probe	For scope or vtvm	1. Signal tracing 2. Signal level measurements
Signal Injector	Multivibrator	1. Signal tracing 2. Go/no-go checks
Walkie-Talkie	1 to 23 channels	1. Ignition noise tracer
Dummy Load	50 ohm	1. Transmitter testing without antenna
TV Receiver	All channel	1. Television interference checks
Antenna System	Base station, 50-ohm	1. Transmitter checks 2. Receiver checks 3. Transceiver match checks
Capacitor Tester	Capacitance, leakage	1. Go/no-go checks 2. Capacitance measurements 3. Leakage measurements

2-3 contains a dummy load as well as a meter, rectifiers, and other components for measuring power and modulation level. The meter measures rectified rf current, and its scale is calibrated in watts and swr (standing-wave ratio).

RF Power Meter

The swr power meter shown in Fig. 2-1 requires an external dummy load. It is intended for connection between an antenna and a transmitter or between a transmitter and a dummy load.

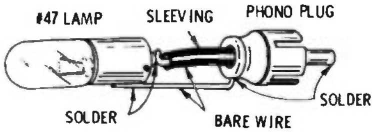
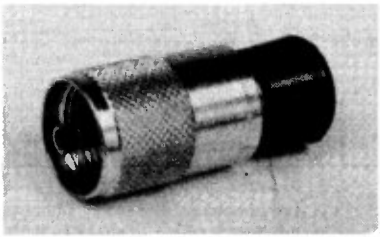


Fig. 2-5. Lamp-type dummy load.

A schematic of a similar instrument is shown in Fig. 2-7. The signal from the transmitter is passed through a directional coupler, a piece of transmission line within the instrument, to the antenna or dummy load. In this particular instrument, J1 and J2 are connected by a



Courtesy Gold Line Connector, Inc.

Fig. 2-6. GLC-1072 50-ohm dummy load.

hollow metal rod. On each side of, and parallel to, this metal rod are two pieces of wire with opposing ends connected alternately by S1 to a rectifier and a meter. The combination of inductive and capacitive coupling is such that the incident rf voltage on the line is balanced out, and the reflected power (returning from the antenna or dummy load) can be measured. The switch can be set to read either incident

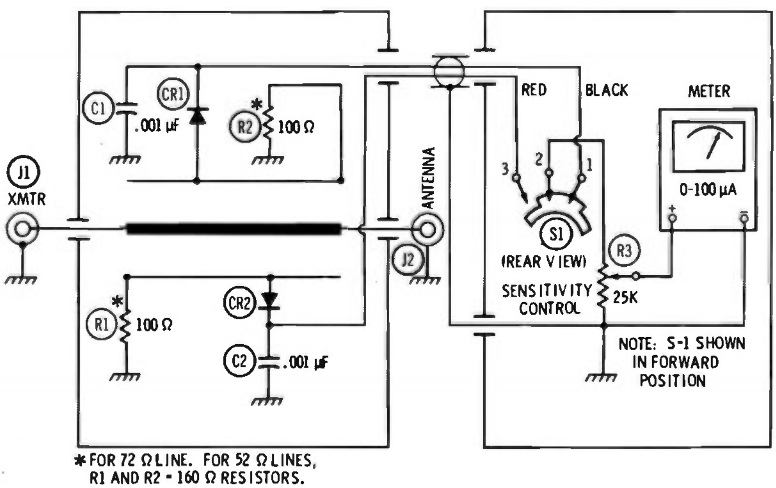
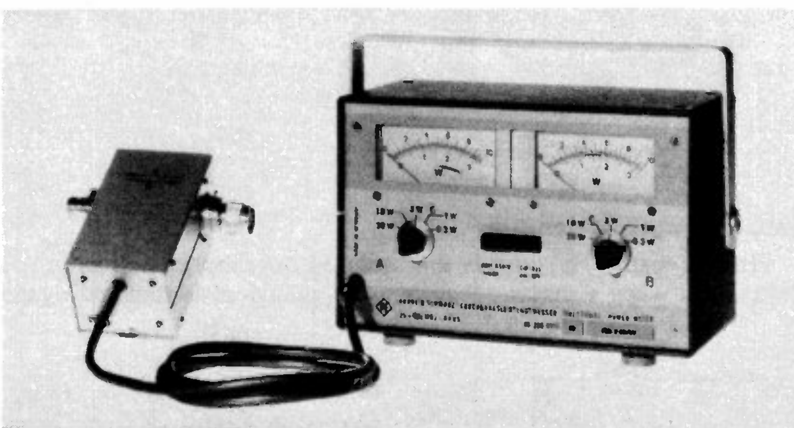


Fig. 2-7. Schematic diagram of through-line type of rf power meter.

or reflected power. Incident power is the power that is delivered by the transmitter. Reflected power is the power reflected back to the transmitter because of mismatch. The difference between these two measurements can be translated into terms of swr (standing-wave ratio) or efficiency.

This kind of rf power meter is more flexible than the loaded or absorption-type rf power meter since it can be used in the shop with a dummy load or in the field to measure antenna efficiency.

The Rhode & Schwartz NAUS directional power meter, shown in Fig. 2-8, simultaneously measures both incident and reflected power with two meters. It has a wide continuous frequency (25 to 525 MHz) and power range (20 mW to 30 W) and can be used over the entire band without frequency-range switching. A separate measuring head, mounted on a flexible cable, permits easy in-service measurement of radio equipment and antenna matching. It has a high sensitivity of 0.3 W for full-scale deflection, low insertion loss, and vswr. There is very little influence on the indication due to temperature changes, such as might be encountered near auto engines. The instrument is small and is battery operated, with a battery lifetime of more than 7000 hours, which makes it ideal for portable use.



Courtesy Rhode and Schwarz

Fig. 2-8. Directional power meter.

SSB Power Meters

It has been customary in the past to use an oscilloscope for the peak envelope power (pep) of an ssb transmitter when it is modulated simultaneously by two audio tones of equal amplitude. Setting up the instruments for such a test is time consuming. The Bird 4314 rf wattmeter (Fig. 2-9) provides a direct indication of pep with a meter.

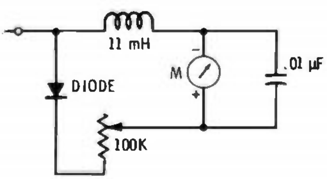
It differs from a conventional rf wattmeter in that it contains a peak comparator amplifier. When measuring the power output of an ssb transmitter, it will follow increases in power and the meter will remain at the highest instantaneous level. Either a scope or peak-reading rf wattmeter is required for measuring pep since an ssb transmitter delivers rf power only when modulated.

Fig. 2-9. Peak-reading rf wattmeter.

Courtesy Bird Electronic Corp.

Field-Strength Meter

Field-strength (FS) meters are useful in the shop as well as in the field. Even when a dummy load is used, enough rf is radiated in the



2-10. Simple field-strength meter of type used for CB.

vicinity of the CB set to get an indication on an FS meter. A simple field-strength meter (Fig. 2-10) consists of a dc microammeter or milliammeter that measures rectified rf current. A short piece of wire connected to the terminal at the upper left suffices as an antenna at short range.

A more sensitive FS meter will contain, in addition to a diode detector, a transistor amplifier with the collector current measured by the meter.

Tube Testers

The simplest tube testers measure cathode emission. More elaborate tube testers measure dynamic mutual conductance. The difference among tube testers is in their ability to detect tube defects. Highly critical tube testers are expensive and generally more difficult to operate. A tube tester is an essential tool, regardless of its type, for culling out tubes that are shorted or weak. One tube fault that is not readily detected by all types of tube testers is grid emission. Some testers, however, are designed to check for this fault, because it is a major cause of equipment instability. Defective tubes which pass muster on a tube tester occasionally make themselves obvious by the manner in which they perform in the set.

Transistor Testers

Since many CB sets employ transistors, the CB shop should be prepared to test them. The simplest type of transistor checker will detect excessive leakage and measure gain. Leakage current is measured with the transistor base disconnected, as shown in Fig. 2-11, and gain is measured by noting the increase in meter reading when S1 is closed to apply forward bias to the transistor base.

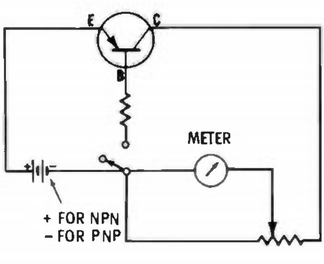
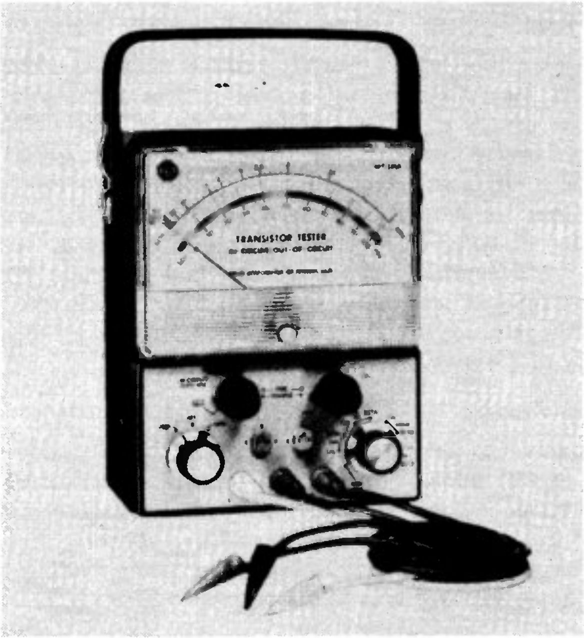


Fig. 2-11. Dc-type transistor checker.

An in-circuit/out-of-circuit transistor checker shown in Fig. 2-12 can be used to check most transistors without removing them from the set. By means of clip leads, the transistor is connected into the tester circuit. Transistor merit is determined by adjustment of the control and by noting the meter reading.

Also available are more elaborate bench-type transistor checkers, which measure gain, leakage current, and (by calculation) other performance characteristics. Switches are usually provided for setting dc voltages to the required levels for different types of transistors and diodes. The transistor tester shown in Fig. 2-13 measures transistor noise and frequency response.



Courtesy RCA

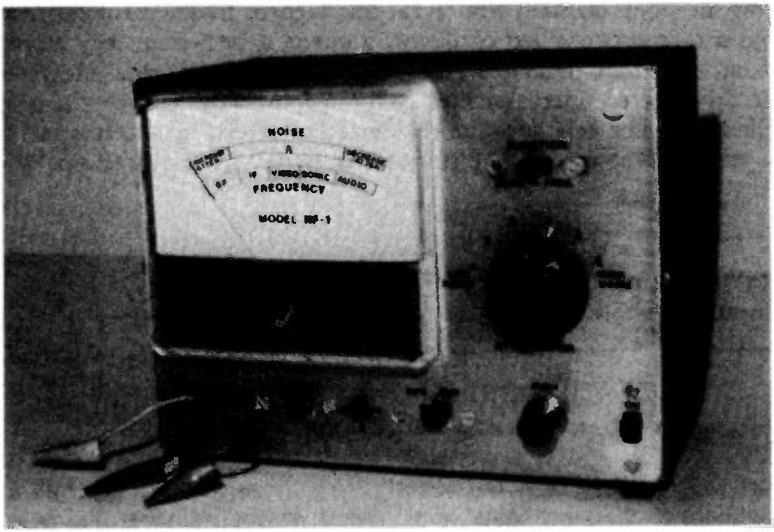
Fig. 2-12. In-circuit/out-of-circuit transistor tester.

Frequency Meters

The most important CB servicing instrument is a frequency meter. It must have an accuracy of at least ±0.0025% to measure CB transmitter frequencies with sufficient accuracy. CB Class-D transmitters must remain within 0.005% of their stated frequency.

Heterodyne frequency meter—Frequency meters suitable for CB servicing range in cost from a little above $200 to $4000 or more. One type is tunable to any frequency in the band. It consists of a variable-frequency oscillator (Fig. 2-14). The output signal (f_1) is mixed with the signal (f_2) of the transmitter being checked. When the two signals are not exactly at the same frequency, the resulting beat frequency (f_3) is fed into the amplifier and then to a speaker or to headphones to make it audible. The frequency-meter dial (vfo tuning) is adjusted for zero beat, and the dial reading is referenced to a calibration curve. Or, if the transmitter frequency can be trimmed, the frequency meter is set to the desired frequency and the transmitter frequency trimmed until zero beat is obtained.

Heterodyne-type frequency meters have the advantage that they can be tuned to any frequency within their range, generally without any modification or addition of accessories. Some contain one or more built-in frequency-reference crystals for checking vfo calibration. Such instruments should be checked against WWV or some other frequency standard at regular intervals.



Courtesy Jud Williams, Inc.

Fig. 2-13. Transistor noise- and frequency-response checker.

The accuracy of measurements made with a heterodyne-type frequency meter depends on the following factors:

1. The accuracy of the instrument,
2. The accuracy with which the instrument dial is read by the user,
3. The accuracy with which the dial reading is interpreted from the calibration curve.

One manufacturer has reduced the human-error factor by furnishin a Citizens-band frequency-reference table with its heterodyne-type

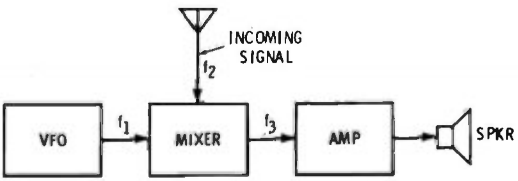


Fig. 2-14. Block diagram of heterodyne frequency meter.

frequency meter. Each instrument is tested at all 23 CB-channel frequencies, and the meter-dial readings for each channel are listed in the reference table. The user merely looks up the channel setting in the table instead of on a calibration curve.

Another basic type of frequency meter in wide use is the so-called "frequency-deviation" type. It compares the frequency of the transmitter with the known fixed frequency and measures the difference. As shown in block diagram Fig. 2-15, this type of frequency meter employs a crystal-controlled oscillator, a mixer, a beat-frequency amplifier, an amplitude limiter, a differentiator, and a pulse-rate integrator that drives a dc microammeter calibrated in kHz. The crystal-controlled oscillator generates the reference frequency, f_2, which is fed to one input of the mixer. The transmitter signal, f_1, is picked up by a

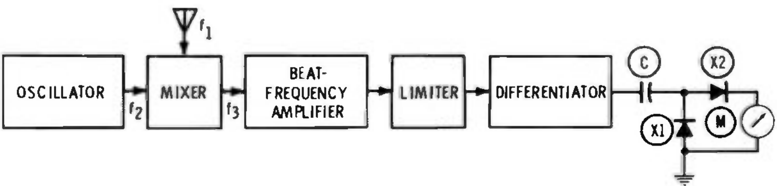


Fig. 2-15. Block diagram of a frequency-deviation meter.

short whip antenna or is fed directly from the transmitter through an attenuator to the other input of the mixer. If frequencies f_1 and f_2 are not exactly the same, a beat frequency (f_3) is generated, which is fed to and amplified by the beat-frequency amplifier. The amplified beat-frequency signal (f_3) is fed to an amplitude limiter, which converts the signal into a square wave. The square-wave output of the limiter is fed to the differentiator, which converts the square wave into positive and negative pulses of equal duration. This train of pulses is then fed to the pulse-rate integrator-metering circuit, which accepts only the positive pulses. Assume, for example, that f_3 is 1000 Hz. This means that positive pulses will flow through meter at the rate of 1000 per second, and the meter will indicate 1 kHz. On the other hand, if f_3 is 100 Hz, the pulses will cause current to flow through the meter at the rate of 100 times per second. The average current through the meter is equal to the amount of time that current passes through the meter. Since the meter cannot respond to the pulses directly, it indicates average current, which increases as the pulse rate increases.

Meters of this type, such as those manufactured by International Crystal Manufacturing Company, can be equipped with up to 24 crystals, which are selected with a front-panel switch. The instrument can be equipped with crystals for all 23 CB channels as well as with a crystal for some other frequency, such as might be used for aligning i-f amplifiers. Typically, such a meter has two frequency ranges, 0 to 5 kHz and 0 to 15 kHz. Frequency-deviation range is selected with a switch that selects the capacitor C value that is used between the differentiator and the indicator circuit. This type of frequency meter is easy to use because it is necessary only to select the channel frequency to be measured and then to note the frequency error on the scale of the meter.

A very popular type of frequency meter employs a frequency synthesizer. The Singer FM-10 comunications monitor, for example, can be set to any frequency between 50 kHz and 512 MHz by means of front-panel knobs. It can be used as a frequency-deviation meter by noting the error frequency on the scale of a front-panel meter. Or, the frequency it generates can be set to the transmitter frequency in order to obtain a zero indication on the frequency-error meter. The frequency is then read from the frequency-selection knobs. As shown in Fig. 2-16, this instrument can be equipped with an oscilloscope for indicating transmitter-signal waveform and modulation level. Also, at the

Courtesy Singer Instrumentation

Fig. 2-16. Singer FM-10C communications monitor.

left is shown a preamplifier that makes it possible to use this instrument for measuring the frequencies of distant transmitters.

The Lampkin 107B frequency meter also utilizes a frequency synthesizer. It generates frequencies from 1 kHz to 1000 MHz and can measure frequencies to an accuracy of 0.00005%. This instrument, as well as the Singer communications monitor, can also be used as a signal generator for receiver alignment.

Easiest of all to use is a frequency counter, such as the one shown in Fig. 2-17. The actual transmitter frequency is indicated in illuminated numerals on the front panel of the instrument.

Courtesy Ballantine Laboratories, Inc.

Fig. 2-17. Electronic frequency counter.

The transmitter signal is fed through an attenuator to the signal-conditioner stage of the electronic counter. The waveform of the signal is transformed into a precisely shaped signal suitable for further counter functions. The shaped signal is fed to a gate for a time interval determined by the gate control/time base. The signal pulses from the gate are then fed to a string of decimal-counting units (DCU's), which in turn drive the illuminated readout.

A very accurate signal from the reference oscillator is fed to the time-base unit (Fig. 2-18) and the output is then fed to the gate control.

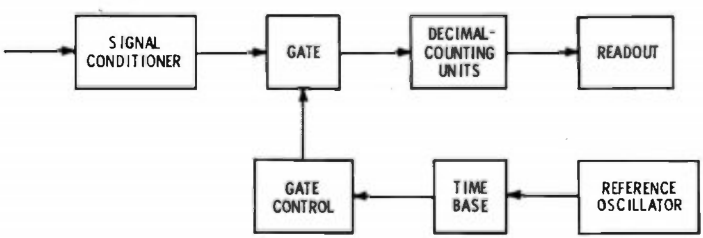


Fig. 2-18. Simplified block diagram of a frequency counter.

An electronic counter and other types of frequency meters can be calibrated against standard-frequency-station WWV. Most often, the 10-MHz signal from WWV is used for checking frequency-meter accuracy. This signal can be interpreted with a multiband short-wave receiver or a receiver designed specifically for receiving transmissions from WWV. In the case of a frequency meter that generates a signal and that can be set to generate a 10-MHz signal, this signal is coupled to the receiver input and observed for a difference in frequency as noted by a beat note. If there is a difference in frequency and the frequency meter is adjustable, it is adjusted so that a zero-beat condition is obtained.

The kind of frequency meter to buy depends on your budget and the scope of the work to be performed. For CB work only, a continuously tunable heterodyne-type frequency meter with an accuracy of 0.0025% or a difference-type instrument equipped with 0.0025%-accuracy crystals for each channel to be measured will suffice.

If you plan to service commercial mobile-radio equipment also, you will need a frequency meter with an accuracy of at least ±0.0001%, since the frequency tolerance is ±0.0005% for the 152- to 174-MHz band and ±0.00025% for the 450- to 512-MHz band.

Signal Generators

One of the handiest CB servicing tools is an all-frequency signal generator. It is generally packaged like a fountain pen and contains a multivibrator with an output signal rich in harmonics and requires no tuning. When its probe is touched to the antenna jack or input of almost any stage in a receiver, an audio tone is heard in the speaker if the set is functioning.

A tunable rf signal generator or frequency synthesizer is required for alignment of receiver i-f and rf circuits. It must be tunable to all of the intermediate frequencies (i-f) of the receivers to be serviced (262.5 kHz to 10.7 MHz) and tunable through the Citizens band (26.96-27.26 MHz).

There is a wide selection from which to choose. Many low-priced signal generators are available, covering frequencies from below 262.5 kHz to 30 MHz or higher. While nearly all signal generators will produce a signal at the required frequencies, not all are satisfactory for CB servicing.

It is important that the signal generator be accurately calibrated and possess high frequency stability. Typically, the calibration accuracy is 2%, which means that at 262.5 kHz the frequency error could be as great as 5.25 kHz, and at 27.025 MHz the error could be as great as 540.5 kHz. This is considerable, since there is only 290 kHz between the carrier frequencies of Citizens-band channels 1 and 23.

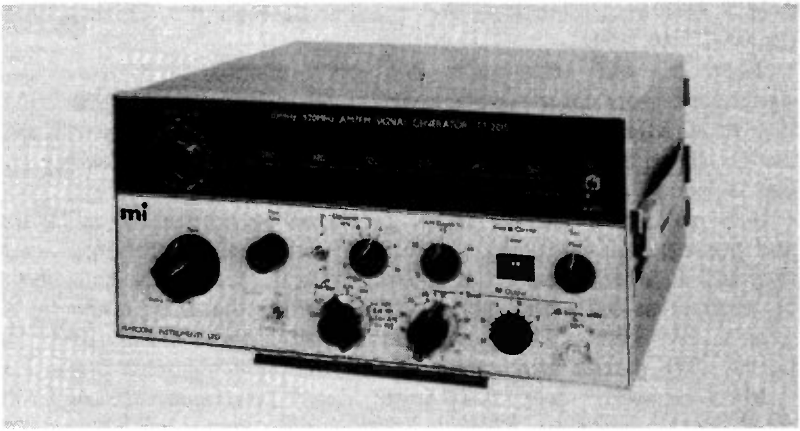
More expensive laboratory-grade signal generators are typically rated at 1% accuracy, which is some improvement, but not enough to permit use of a signal generator as a frequency standard. Since it is often necessary to be able to set a signal generator to the desired frequency with great accuracy, an external frequency standard can be of great value.

For setting a signal generator accurately to an i-f, such as 262.5 kHz, 455 kHz, or 1650 kHz, etc., a military-surplus BC-221 frequency meter can be used. The BC-221 covers the 100- to 20,000-kHz range and is available from many sources at bargain prices.

For setting a signal generator *fairly* accurately to one of the CB channels, an incoming signal can be used as a reference. However, a frequency meter is much better for this purpose, because of the possibility that the incoming signal may be off frequency.

Attenuators—Another requirement of a signal generator is the ability to attenuate its output to less than 1 microvolt. While the dials on a low-cost signal generator might indicate that the output is set for 1 microvolt, due to inadequate shielding there may be so much signal leakage past the attenuator and through the case that the signal reaching the receiver may be considerably stronger.

There are many signal generators suitable for CB servicing. Most are not sold through electronic-parts distributors; they are usually sold by manufacturers' representatives or factory-employed sales engineers. The Marconi 2015, shown in Fig. 2-19, is an example of a relatively low-cost, high-precision signal generator. It is tunable from 10 MHz to 520 MHz in 11 bands and can be operated from the ac power line or battery. Its rf output signal can be an unmodulated carrier, or it can be amplitude modulated or frequency modulated. For i-f alignment at frequencies below 10 MHz, a lower-cost, general-purpose signal generator can be used.



Courtesy Marconi Instruments, Ltd.

Fig. 2-19. Marconi 2015 rf signal generator.

Frequency meter as signal generator—A frequency meter is often used as a signal generator because of its known frequency accuracy. Some are equipped with an rf output jack to permit direct connection to a receiver and with an attenuator to vary the rf output. When the instrument is not equipped with an rf output jack, the signal is picked up by placing the frequency meter, or its pickup antenna, as close to the receiver as necessary.

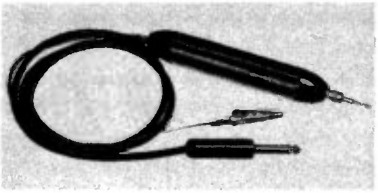
Wave Analyzers

Another instrument that is being used more widely, but is not an essential one, is a wave analyzer, or distortion meter. It is required for making SINAD receiver sensitivity measurements and is useful for measuring modulation and audio-receiving distortion. These instruments are essentially frequency-sensitive vacuum-tube voltmeters, which can be used to measure the strength of the harmonics of a test tone.

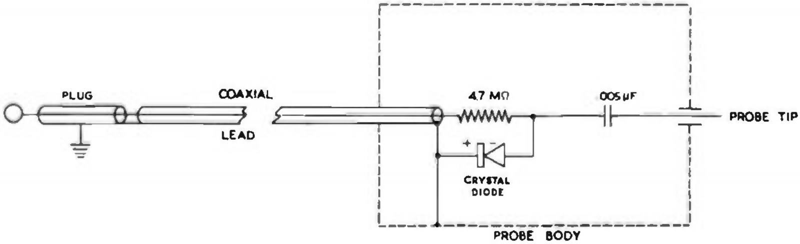
Test Meters

Every electronics technician needs a volt-ohm-milliammeter (vom) for routine measurements and troubleshooting. One of the 20,000-ohms-per-volt type is preferable to one of the lower resistance to avoid undue loading of high-resistance circuits.

A vacuum-tube voltmeter (vtvm) or solid-state equivalent is another essential tool for measuring and monitoring avc voltage. If equipped with an rf probe (Figs. 2-20A and 2-20B), a vtvm can be used for measuring rf voltages at CB operating frequencies.



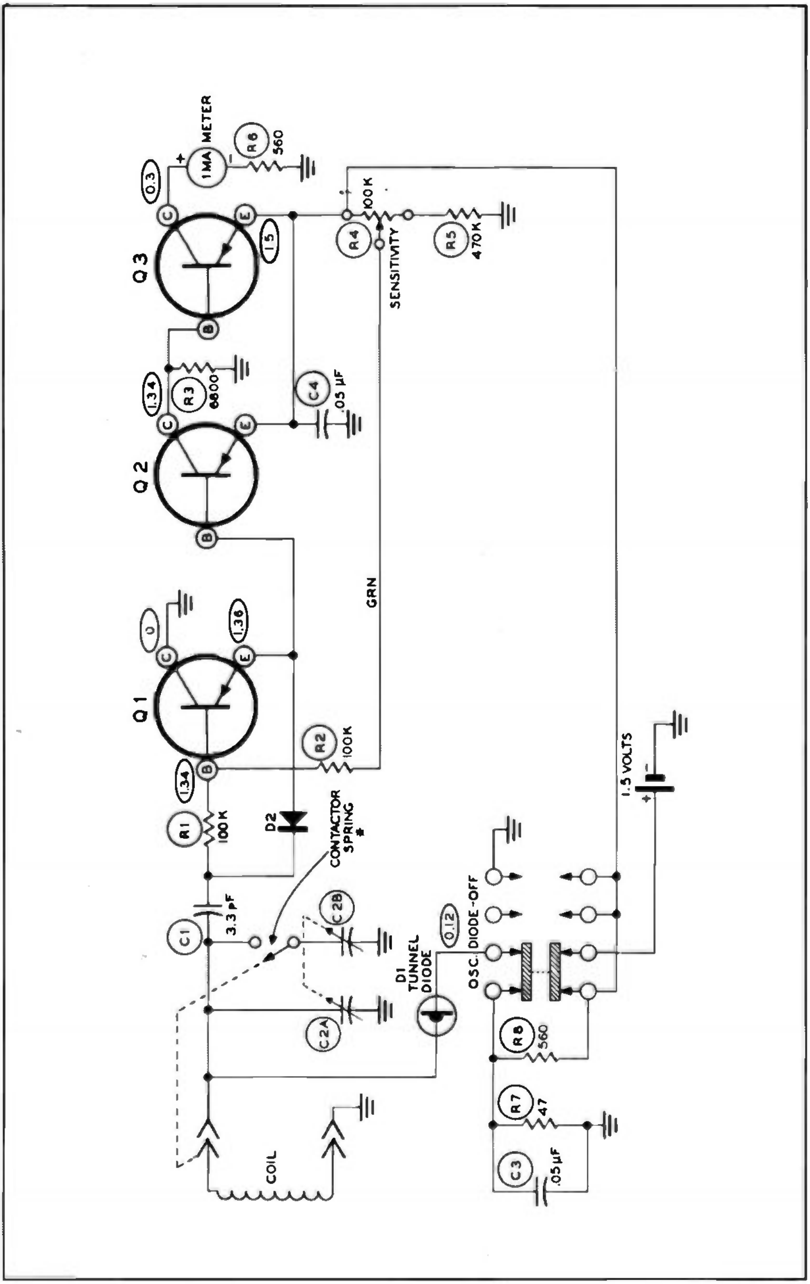
(A) Model W-309C rf probe assembly.



(B) Schematic of rf probe.

Courtesy Heath Co.

Fig. 2-20. Rf probe.



Courtesy Heath Co.

Fig. 2-21. Resonance meter.

Grid-Dip Meters

A grid-dip meter is handy to have for checking out tuned circuits. A shorted turn in a coil or an open low-value capacitor may be hard to detect, except by measuring the frequency at which the tuned circuit is resonant. There are several grid-dip meters on the market that are tunable through the CB range.

One of the interesting devices of this type is not actually a grid-dip meter, but it performs the same functions. As shown in Fig. 2-21, it employs a tunnel diode as an oscillator and a transistor meter amplifier. When its coil is placed close to the coil of a tuned circuit and the oscillator is tuned to the resonant frequency of the tuned circuit being checked, the meter needle dips as in a grid-dip meter. Plug-in coils provide coverage from 3 MHz to 260 MHz.

Oscilloscope

Since its introduction during the depression as a radio-servicing instrument, the oscilloscope has been in the do-you-really-need-it category. For servicing tv sets it is essential, but many radio servicemen have chosen to ignore it, mainly because they do not understand its capabilities.

For servicing CB sets, a scope is very useful for measuring modulation. For measuring modulation using the trapezoid-pattern method, direct access to the vertical-deflection plates of the scope tube is required. Some scopes are equipped with terminal boards for this purpose. For observing the rf carrier envelope, the scope vertical-amplifier channel must be able to handle frequencies in the megahertz region.

One way to measure modulation percentage is to modulate the transmitter with a 1000-Hz sine-wave tone and note the increase in rf power or voltage output. When 100% modulated, power output will rise 50% above the unmodulated carrier level and voltage will rise 22.5%.

A better way is to observe the modulation envelope on the screen of an oscilloscope with a vertical input bandwidth of at least 30 MHz. The scope can be connected to the transceiver antenna receptacle through a coaxial T-connector, as shown in Fig. 2-22. To use a general-

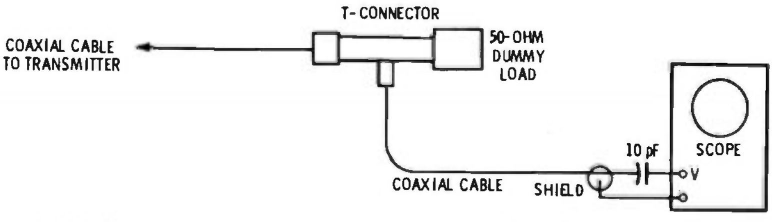


Fig. 2-22. Scope connected to a transmitter and dummy load through a T-connector.

purpose scope for this purpose, a down-converter is required, connected as shown in Fig. 2-23. An alternative is to use a receiver to which the vertical input of the scope is connected through a capacitor, as shown in Fig. 2-24. Examples of scope patterns for various levels of modulation are illustrated in Fig. 2-25.

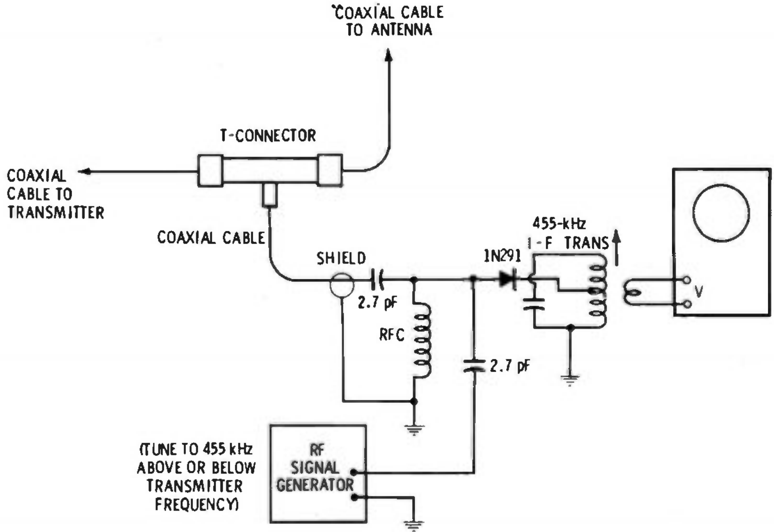


Fig. 2-23. Scope connected to a transmitter through a down-converter.

Since the wave-envelope pattern varies continuously with modulation, it is difficult to obtain an accurate modulation-percentage measurement using this method. However, this type of presentation provides a means of quickly detecting overmodulation.

When the oscilloscope is connected as shown in Fig. 2-26, the waveform shows the modulated carrier amplitude plotted as a function of the modulating voltage—rather than as a function of time. The waveform resulting from the use of the modulating voltage as a sweep

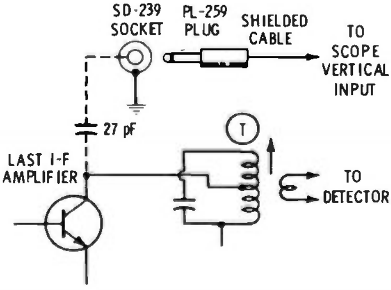
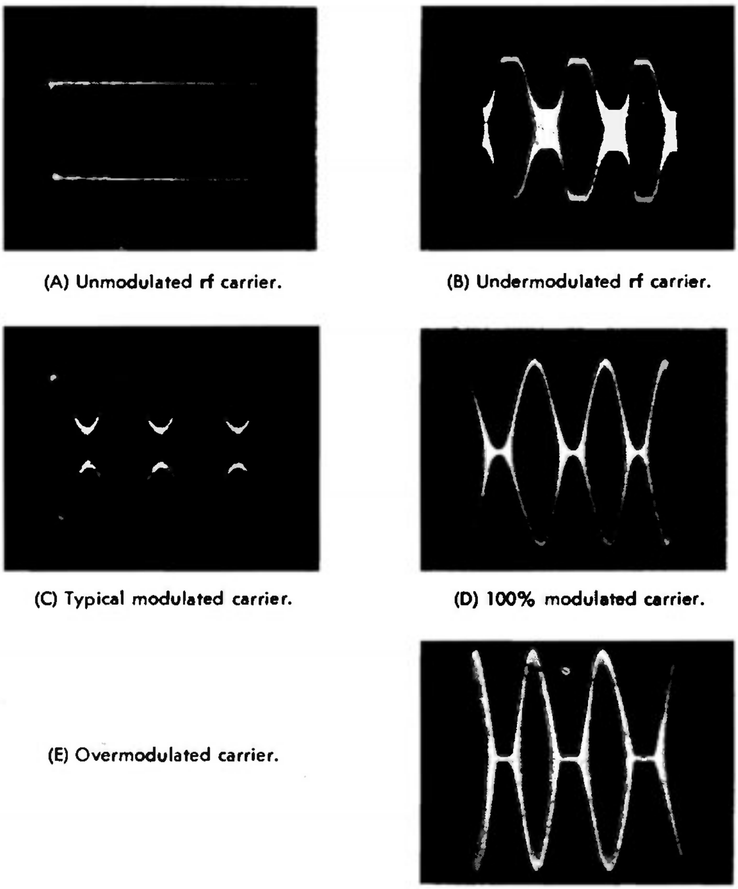


Fig. 2-24. Scope connected to a receiver.

is known as a trapezoidal pattern. This type of pattern is used to determine the modulation percentage. With no modulation applied, a single vertical trace, which represents the carrier voltage, appears on the oscilloscope screen. The vertical trace is centered horizontally, and then its height is set to an arbitrary number of divisions by means of the vertical-level control. When modulation is applied, the pattern



(A) Unmodulated rf carrier.

(B) Undermodulated rf carrier.

(C) Typical modulated carrier.

(D) 100% modulated carrier.

(E) Overmodulated carrier.

Fig. 2-25. Modulation envelope patterns.

assumes trapezoidal characteristics, as shown in Fig. 2-27. The oscilloscope horizontal-level control should be adjusted to provide a usable pattern within the limits of the screen. By counting the number of divisions that the modulating voltage causes the carrier amplitude to increase or decrease (indicated by H_1 and H_2, respectively) from its former level (X) and substituting that value in the formula given below, it can easily be calculated that the modulation percentage is as follows:

$$\text{Modulation percentage} = \frac{H_1 - H_2}{H_1 + H_2} \times 100$$

where,

H_1 is the amplitude of the crest of the modulated carrier,
H_2 is the amplitude of the trough of the modulated carrier.

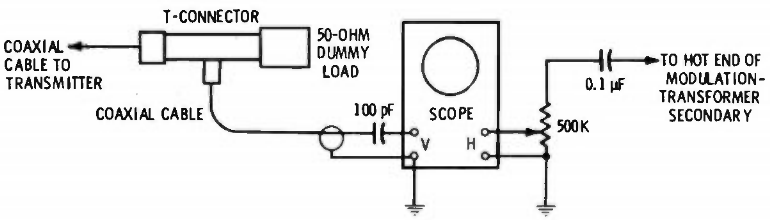


Fig. 2-26. Scope hookup for trapezoidal patterns.

The longer side of the trapezoidal pattern represents modulation peaks, or crests; the shorter side indicates modulation troughs, or low points. At 100% modulation, the wedge-shaped pattern assumes a point on the shorter side. Modulation over 100% causes this point to extend and form a horizontal line or tail. Because the trapezoidal pattern retains its triangular characteristics with varying degrees of modulation, it provides an easily discernible indication of overmodulation.

Another method for measuring the percentage of modulation of an a-m signal is shown in Fig. 2-28. This method requires the use of a receiver tuned to the transmitter frequency. After oscilloscope connections are made, it may be necessary to retune the i-f stage to compensate for additional loading effect. The oscilloscope pattern is an ellipse having a single sharp line and is the result of a phase difference between the vertical- and horizontal-deflection voltages fed to the oscilloscope. This phase difference is produced by the horizontal-amplifier input capacitance and the 51,000-ohm resistor.

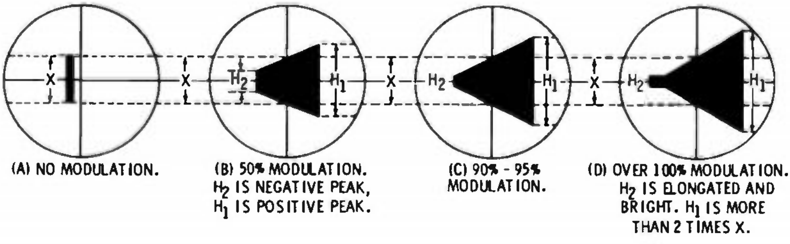


Fig. 2-27. Trapezoidal patterns.

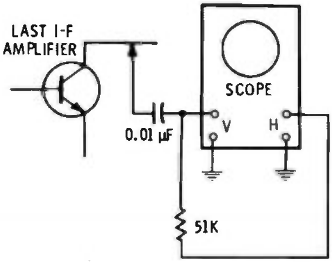


Fig. 2-28. Scope hookup for elliptical patterns.

As shown in Fig. 2-29, the unmodulated pattern is an ellipse having a single, sharp line. This line broadens to a ribbon with modulation. For 100% modulation, the dark area in the center of the pattern decreases to zero. This point may be determined with accuracy. Overmodulation goes beyond this point, and a bright spot appears in the center of the pattern. The modulation percentage may be calculated by the formula given below.

$$\text{Modulation percentage} = \frac{D_1 - D_2}{D_1 + D_2} \times 100$$

where,

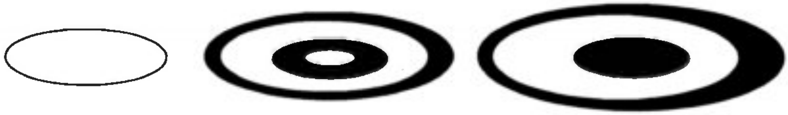
D_1 is amplitude at the crest of the signal,
D_2 is amplitude at the trough of the signal.

Crystal Checkers

Crystals can usually be checked by measuring receiver or transmitter performance, and by trying new crystals. An external crystal checker can be used for determining relative activity of a crystal. The crystal is merely plugged into the checker, and its relative activity is indicated on a meter. The crystal is operated in an oscillator circuit in the tester, which may also be used as a signal generator for receiver alignment.

Shop CB Set

A CB set is a handy shop test instrument. For this purpose the set should be one of the types that can transmit and receive on all 23 channels. The transmitter is used as a frequency reference or signal generator, for receiver alignment. It can also be used for making quick transmitter frequency checks. The receiver can be used for making



(A) Unmodulated signal. (B) Modulated signal. (C) Overmodulated signal.

Fig. 2-29. Elliptical modulation waveforms.

modulation measurements when used with a scope, and it can also be used as part of a transmitter frequency-measuring setup. Procedures for using CB sets as test instruments are explained later.

By adding an external S-meter, available in kit or wired form, a shop CB receiver which does not have a built-in S-meter can be used as high-sensitivity field-strength meter.

Bench Power Supply

When servicing CB sets in a shop, it is essential to simulate actual operating conditions. In a vehicle the battery voltage can vary from 11 to 15 volts in 12-volt-equipped cars, and from 5.5 to 7.5 volts in 6-volt-equipped cars. Receiver sensitivity and transmitter power output vary widely with battery voltage. When voltage is high, the receiver might burst into oscillation and transmitter power output might exceed the legal limit of 4 watts.

Since some CB sets operate from a 6-volt source, it is essential to have both 6- and 12-volt bench power supplies. Two 6-volt batteries can be used in series to get 12 volts, and 6 volts at their junction. But, batteries alone will not give you a variable-voltage power source. If you float a battery charger (Fig. 2-30) across the batteries, you can vary the voltage by turning the charger on and off.

An ammeter in the common power lead (Fig. 2-30) makes trouble diagnosis easier, since you can tell immediately if input current is lower or higher than normal. A 0-15 dc ammeter, protected by a fuse, is suitable for this purpose.

Rectifier power supply—Several variable-voltage rectifier power supplies on the market can be adjusted to deliver from 0 to 15 volts dc output. A typical circuit is shown in Fig. 2-31. The ac line voltage is stepped down by transformer T, whose secondary has numerous taps selected by a switch. The low ac voltage is rectified by a full-wave bridge rectifier and filtered by L, C1, and C2. A dc voltmeter and dc ammeter provide load voltage and current indications.

Variable ac voltage source—While the nominal ac line voltage is 120 volts, it can be anywhere from 105 to 130 volts in some areas. If a CB set is operated at too high or too low a voltage, performance is affected. Since wide variations in line voltages are apt to be encountered by customers, it is a good idea to check out sets in the shop

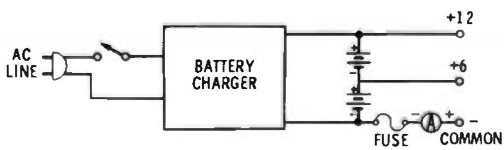


Fig. 2-30. A 6/12-volt battery power supply.

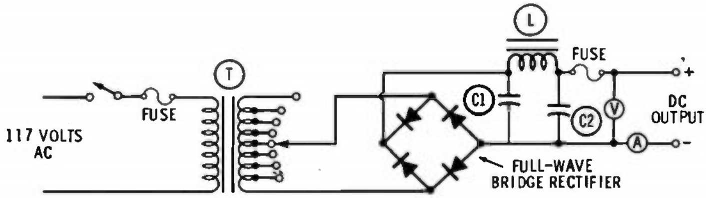
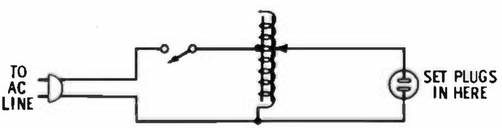


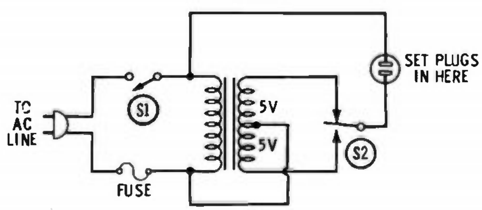
Fig. 2-31. Variable dc power supply.

at the extreme limits of line voltage. To do this, a variable autotransformer may be connected between the ac line and the set. The voltage to the set can be varied from 0 to 135 volts. Fig. 3-32A is a schematic of such a device. The voltage is varied by adjustment of a knob, which varies the turns ratio of the autotransformer.

Input voltage can be stepped up or down 5 volts by employing a center-tapped 10-volt filament transformer as an autotransformer (Fig. 2-32B). When the spdt switch is set in one position, the line voltage is boosted 5 volts (half of the secondary voltage), and when the switch is set in the other position, the line voltage is dropped 5 volts.



(A) Variable autotransformer.



(B) Buck-boost transformer circuit.

Fig. 2-32. Variable ac power supplies.

Useful Life of Test Equipment

When test equipment is purchased, the investment must be justified by the monetary return that can be realized. Most test equipment can be expected to have a useful life of 10 years. However, sometimes equipment is obsolesced more rapidly if FCC regulations or manufacturers' standards are tightened.

CHAPTER 3

Frequency Selection and Control

A typical CB set employs at least two oscillators for generating an rf signal. One is the transmitter oscillator, which must be crystal controlled; the other is the receiver local oscillator, which is usually crystal controlled.

TRANSMITTER OSCILLATORS

The transmitter section of a CB set must be crystal controlled so that it will operate within ±0.005% of the selected operating frequency. A block diagram of a typical CB transmitter is shown in Fig. 3-1. The oscillator operates at a frequency determined by the crystal that is in use. To change frequency of a single-channel transmitter, the crystal is replaced. In a multichannel transmitter, the channel selector is set to select the desired crystal.

The unmodulated high-frequency output of the oscillator is fed to the rf power amplifier, which usually operates at the same frequency as the oscillator. The crystal may be of the third-overtone type, i.e., a crystal which is ground to one-fourth of the operating frequency, but exercises frequency control at its fourth harmonic (third overtone).

When unmodulated, the rf power amplifier feeds a continuous-wave (cw) signal into the antenna system. This signal (f_1) is of constant amplitude and frequency. But, when modulated, the signal being fed into the antenna varies in amplitude at audio modulating rate f_2. The signal is no longer a single frequency. Instead, it consists of a carrier at oscillator frequency f_1, and two sidebands. The width of the upper and lower sidebands produced by amplitude modulation is equal to the audio modulating frequency (f_2). If the highest modulating frequency is 3000 Hz, the radiated signal occupies spectrum space extending from $f_1 - f_2$ to $f_1 + f_2$; hence the signal, called A3 emission, occupies 6 kilohertz of the radio spectrum.

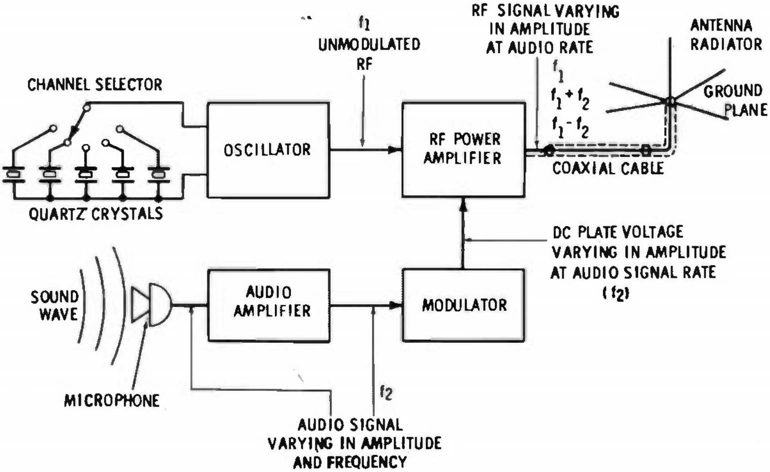


Fig. 3-1. Signal paths through a typical CB transmitter.

RECEIVERS

The radiated signal must be demodulated in order to use the audio signal. At a very short distance, the receiver could consist simply of a detector and an audio amplifier. The signal at the input of the detector includes f_1, $f_1 + f_2$, and $f_1 - f_2$. At the output of the detector, f_2 is passed through an amplifier and then converted back into sound waves by a speaker.

A practical CB-receiver block diagram is shown in Fig. 3-2. The incoming A3 signal (f_1, $f_1 + f_2$, and $f_1 - f_2$) is amplified and heterodyned in the mixer stage with local-oscillator signal f_3, which is of constant frequency and amplitude.

If f_3 is lower than f_1, the output of the mixer contains frequencies including $f_1 + f_3$, $(f_1 - f_3)$, $(f_1 + f_2) + f_3$, $(f_1 + f_2) - f_3$, $(f_1 - f_2) + f_3$, and $(f_1 - f_2) - f_3$. The output of the mixer is tuned to f_4, which is equal to $f_1 - f_3$, and the i-f amplifier passes f_4, $f_4 + f_2$, and $f_4 - f_2$ when receiving an a-m signal.

If incoming carrier f_1 is at 27.025 MHz and local-oscillator signal f_3 is at 26.570 MHz, i-f signal f_4 will be at 455 kHz. The incoming signal, when amplitude modulated at 3000 Hz, will extend from 27.022 MHz to 27.028 MHz (6 kHz wide). The i-f signal will extend from 452 kHz to 458 kHz.

This double-sideband a-m signal, after amplification, is demodulated by the detector, and only f_2 remains. This signal is amplified by the audio amplifier and converted into sound by the speaker.

Fig. 3-2 shows that the local oscillator can be set to any of five frequencies by selecting the appropriate crystal. Each of these crystals operates at a frequency of 455 kHz below the desired receiving frequency. (The same intermediate frequency could be produced by making local-oscillator frequency f_3 455 kHz higher than f_1.)

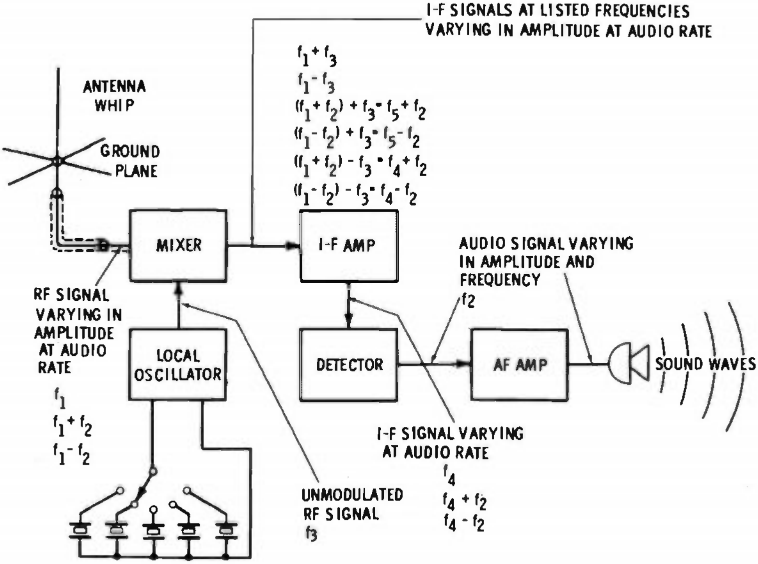


Fig. 3-2. Signal paths through a typical CB receiver.

FREQUENCY STABILITY

To meet FCC technical standards, the transmitter frequency must not vary more than ±0.005% from the channel frequency. This means that at 27.025 MHz, for example, the transmitter carrier frequency must remain within 1351 Hz of 27.025 MHz, since 27.025 MHz × 0.005% equals 1.351 kHz or 1351 Hz (0.005% = 0.00005).

While the receiver local oscillator does not have to be crystal controlled, it is important that its frequency setting remain relatively stable. This is particularly true in highly selective receivers. If the incoming signal is at 27.025 MHz and the i-f is 455 kHz, the local oscillator is normally tuned to 26.570 MHz. If the local oscillator drifts, the i-f will no longer be at 455 kHz. If the receiver bandwidth is narrow, distortion and reduced sensitivity will result when the local oscillator drifts excessively.

CRYSTALS

The original crystals furnished by the manufacturer of the CB set were ground specifically for use in that particular make and model. When replacement crystals are installed or when channels are added, it is best to obtain crystals from the maker or the distributor of the CB unit. When ordering crystals directly from a crystal manufacturer or through a parts distributor, the make and model of the CB set should be specified. The frequency of a crystal oscillator is determined not only by the crystal, but also by the capacitance and inductance of the associated circuitry.

Using Stock Crystals

Citizens-band crystals that have been ground for use in circuits under "typical" conditions are available at radio-parts distributors and from mail-order houses. In some sets, they will operate at the labelled frequency within the legal 0.005% tolerance. In other sets, their use may result in unlawful, off-frequency operation.

Whenever installing new crystals in a customer's transmitter, always measure the frequency before turning the set over to the customer. Failure to do so may put the customer in jeopardy of being cited by the Federal Communications Commission for off-frequency operation.

DELTA TUNE

Although the transmitting and receiving frequencies of CB transceivers are supposed to be held by crystals to within ±0.005% of a channel frequency, some receivers have a "delta-tune" feature that permits clear reception of off-frequency signals. This feature can be provided by using three crystals in the second local oscillator of a double-conversion receiver. In the center position, the delta-tune switch selects a crystal for on-frequency reception. In the "+" and "−" positions, the switch selects a crystal that provides the correct i-f when the incoming signal is above or below the normal frequency of the channel being received.

FREQUENCY MULTIPLIERS

Some CB transmitters employ an oscillator that operates at a lower frequency than the operating frequency. The crystal-oscillator frequency is a submultiple of the operating frequency. For transmission on 27.025 MHz, for example, the oscillator could operate at 13.5125 MHz. This signal is then passed through a frequency doubler to obtain the correct transmission frequency.

DOUBLE-CONVERSION RECEIVERS

Double-conversion superheterodyne receiver circuits are used in many CB sets in order to achieve better selectivity. Fig. 3-3 is a block diagram of this type of receiver. Incoming rf signal f_1 is heterodyned to a lower frequency (f_4) by mixing it with local-oscillator signal f_3.

This i-f signal (f_4) is heterodyned down to a still lower frequency (f_6) by mixing f_4 with another local-oscillator signal (f_5). If f_1 is at 27.025 MHz and f_3 is at 16.325 MHz, f_4 will be at 10.7 MHz. If f_4 at 10.7 MHz is mixed with f_5 at 10.245 MHz, f_6 will be at 455 kHz. The resulting f_6 beat signal, with its sidebands, will extend from 452 kHz ($f_6 - f_2$) to 458 kHz ($f_6 + f_2$) when an a-m signal, modulated at 3000 kHz, is received.

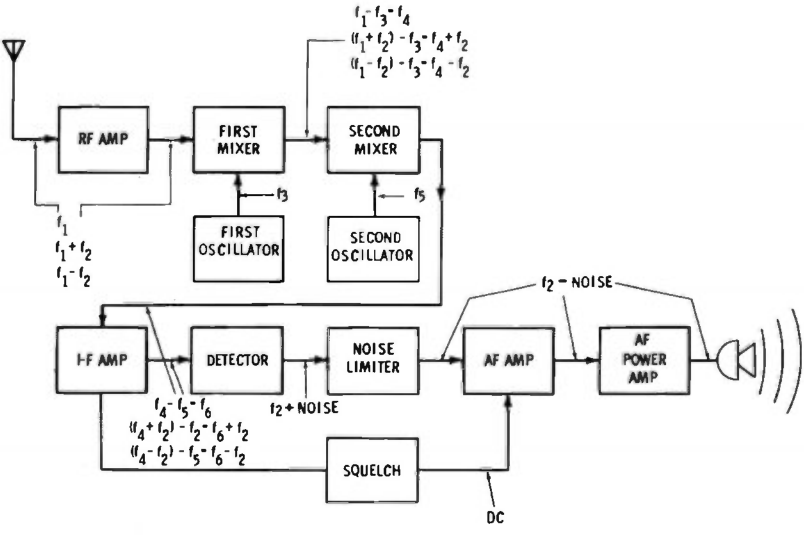


Fig. 3-3. Double-conversion receiver block diagram.

CHANNEL SELECTION

As pointed out earlier, the transmitter frequency is determined by the crystal used in the oscillator. The frequency at which the receiver will be most sensitive depends on the frequency of the local oscillator in a single-conversion superheterodyne receiver. In a fixed-tuned, crystal-controlled single-channel receiver, it is necessary to change the crystal when changing receiving frequency. In a multichannel receiver, the channel-selector switch is set to select the required crystal. In a tunable receiver, the oscillator can be tuned over a frequency range extending from 26.96 MHz to 27.26 MHz plus or minus the i-f.

In a double-conversion superheterodyne receiver, frequency may be changed by changing the frequency of either the first or second local oscillator. This is done by changing crystals or by switching in the correct crystal with the channel-selector switch. In a tunable receiver, the second oscillator is generally tunable over a 290-kHz range to permit selection of any of the 23 channels.

FREQUENCY SYNTHESIZERS

Most modern CB transceivers are factory equipped with crystals for transmitting and receiving on all 23 Class-D CB channels. If conventional techniques were used, 46 crystals would be required, two for each channel. To avoid the use of so many crystals, a frequency synthesizer is used. Only 14 crystals are used to generate 46 different frequencies in the frequency-synthesizer circuit shown in Fig. 3-4 (only two of the crystals are shown in this simplified diagram).

When crystal Y1 causes the frequency of oscillator 1 to be 5.735 MHz (f_L) and crystal Y2 causes the frequency of oscillator 2 to be 32.7 MHz (f_H), their difference beat frequency will be 26.965 MHz (f_T), the Channel 1 transmit frequency. Oscillator 1 feeds its f_L signal through C4 to the base of mixer transistor Q3, and oscillator 2 feeds its f_H signal through rf transformer T to the emitter of Q3. The frequency of the desired signal developed across L1-C11 is 26.965 MHz (32.7 minus 5.735).

To transmit on 27.065 MHz (Channel 9), Y1 remains in the circuit and Y2 is replaced by a 32.8-MHz crystal; f_L remains at 5.735 MHz, f_H is now 32.8 MHz, and f_T is 27.065 MHz—the difference beat frequency of f_H and f_L (32.8 minus 5.735). Although not shown in the diagram, a double-deck, three-position rotary switch is used for selecting any of eight crystals for Y1 and any of six crystals for Y2. The switch is wired so that the required pair of crystals is selected for transmitting on any of the 23 channels.

When two signals are fed to a mixer, more than one frequency is generated. If one signal is at 5.735 MHz (f_L) and the other is at 32.7 MHz (f_H), both of these frequencies will modulate the mixer collector current as will the difference beat frequency (26.965 MHz) and the sum beat frequency (38.435 MHz). In addition, harmonics of f_L and f_H can be generated along with numerous beat frequencies. Since L1 is tuned to be resonant at the desired beat frequency, the amplitude of the undesired frequencies is much lower than that of the desired frequency.

Since channel selection is accomplished only by crystal switching and L1 is not retuned when changing channels, L1 must be broadly resonant so that it will pass all signals between 26.965 MHz and 27.255 MHz. But, if it is broadly resonant, it will not adequately

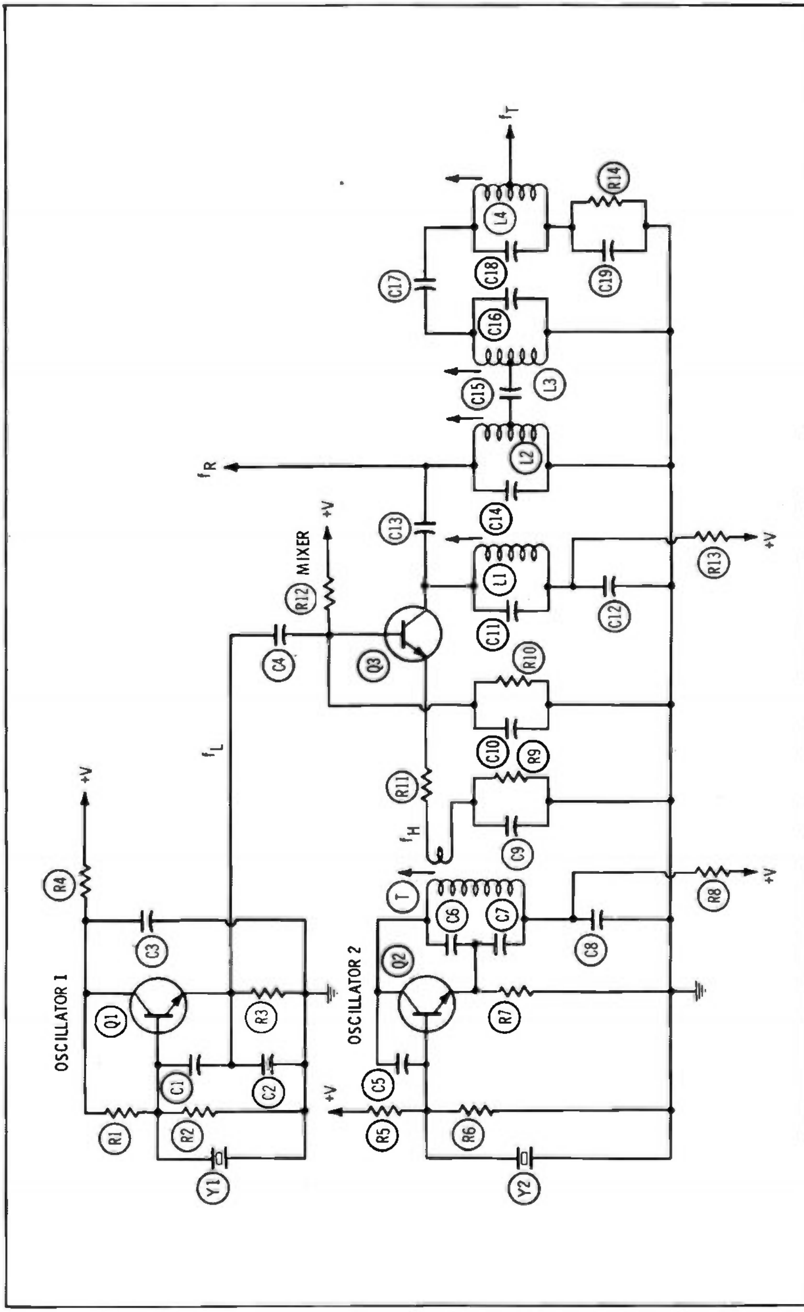


Fig. 3-4. Simplified circuit of a frequency synthesizer.

attenuate undesirable frequencies. To prevent radiation of these undesirable frequencies, the output of L1 is fed through C13 to a three-section bandpass filter comprised of L2, L3, and L4, each shunted by a fixed capacitor to make them resonant at Citizens-band frequencies. All four variable inductors (L1, L2, L3, and L4) are compromise tuned so that all CB-channel frequencies will be passed by the filter. Collectively, these resonant circuits adequately attenuate undesirable frequencies.

In addition to generating 23 different CB-channel carrier frequencies for the transmitter, the synthesizer also generates 23 different local-oscillator frequencies for the receiver. These local-oscillator frequencies are 455 kHz lower than the channel-receiving frequencies, since the transceiver in which this particular synthesizer is used contains a single-conversion receiver with a 455-kHz i-f amplifier.

To receive on Channel 1 (26.965 MHz), f_L is 6.19 MHz and f_H is 32.7 MHz. Their difference beat frequency (f_R) is 26.51 MHz. When f_R is mixed with a 26.965-MHz intercepted radio signal, a 455-kHz i-f signal will result (26.965 minus 26.51). When the channel-selector switch is set to Channel 1 and the transceiver is in the receive mode, a 6.19-MHz crystal (Y1) is connected to oscillator 1 and a 32.7-MHz crystal (Y2) is connected to oscillator 2 so that a 26.51-MHz (f_R) signal will be generated and 26.96-MHz signals can be received. In the transmit mode, an electronic switch automatically disconnects the 6.19-MHz crystal and connects a 5.735-MHz crystal in its place so that a 26.965-MHz (f_T) signal will be generated to enable transmission on Channel 1.

Various other frequency-synthesizing techniques are used. A block diagram of a frequency-synthesis system used in a transceiver containing a dual-conversion receiver is shown in Fig. 3-5. When transmitting, three oscillators and two mixers are used. When receiving, two of the same oscillators, plus a third oscillator, and one of the same mixers, plus two other mixers, are used.

Oscillator 1 operates at any of six selected frequencies between 23.29 MHz and 23.54 MHz, and oscillator 2 operates at any of four frequencies between 14.95 MHz and 14.99 MHz. The outputs of these two oscillators are fed to mixer 1, which has an output frequency that is the sum beat frequency of the frequencies generated by oscillator 1 and oscillator 2.

When the channel-selector switch is set to Channel 1, for example, oscillator 1 operates at 23.29 MHz (f_1) and oscillator 2 operates at 14.95 MHz. Their 38.24-MHz (f_3) sum beat frequency is fed from the output of mixer 1 to the input of mixer 2. Oscillator 3 always operates on 11.275 MHz (when transmitting). Its output signal (f_4) is heterodyned with the 38.24-MHz (f_3) signal to produce their 26.965-MHz (f_5) difference beat frequency at the output of mixer 2.

When receiving on Channel 1, the 38.24 MHz (f_3) signal from the output of mixer 1 is fed to the first mixer (mixer 3) of the receiver. When a 26.965-MHz signal (f_6) is intercepted, it is heterodyned with the 38.24-MHz (f_3) signal and a 11.275-MHz (f_7) difference beat frequency is generated. This first i-f (f_7) signal is fed from the output of mixer 3 to the input of the second mixer (mixer 4) of the receiver, where it is heterodyned with a 11.73-MHz (f_8) signal from oscillator 4. The resulting difference beat frequency (f_9) is at 455 kHz. This 455-kHz second i-f signal (f_9) is fed from the output of mixer 4 through a selectivity filter to the i-f amplifier.

By operating the channel-selector switch from Channel 1 through Channel 23, f_3 is varied in 23 steps from 38.24 MHz to 38.53 MHz by selecting appropriate crystals for oscillator 1 and oscillator 2. At each channel setting, f_3 is 11.275 MHz higher than the channel frequency. The f_3 signal is down converted by mixer 2 and oscillator 4 to the selected channel frequency when transmitting. And when receiving, the f_3 signal is fed to mixer 3 and the intercepted on-channel frequency is down converted to 11.275 MHz and fed to mixer 4.

In a typical 23-channel a-m/ssb transceiver, 17 crystals are used to enable either upper sideband (usb) or lower sideband (lsb) at each setting of the channel selector. A separate switch is used to set the transceiver in the usb, lsb or a-m mode. In the usb and lsb modes, only the selected sideband is transmitted and the carrier is suppressed. In the a-m mode, the carrier and only one sideband (usually upper) are transmitted.

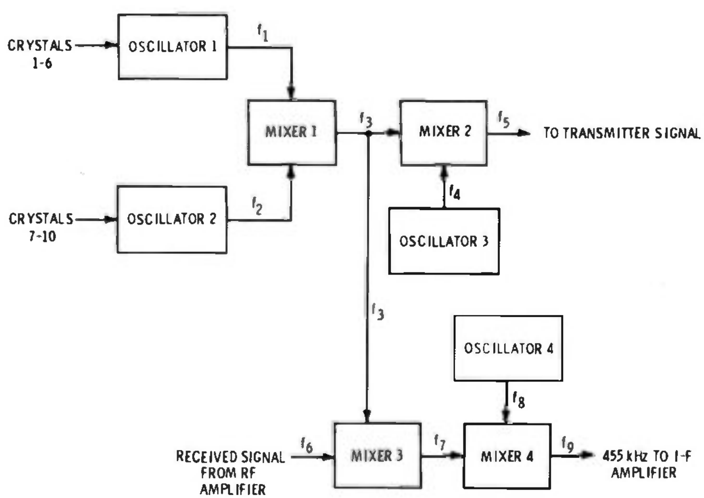


Fig. 3-5. Block diagram of a frequency synthesizer system used in a dual-conversion receiver.

Crystal frequencies and synthesizer circuits vary among ssb-only and a-m/ssb transceivers. In the transceiver selected for discussion, the crystal combinations for all 23 channels are given in Chart 3-1. Note that the frequencies of the crystals used in the lsb group are 3 kHz lower than those used in the usb group.

Chart 3-1. Frequency-Synthesizer Crystal-Combination Chart

	Main Crystal Group						
Lower SB Group	11.705 MHz	11.755 MHz	11.805 MHz	11.855 MHz	11.905 MHz	11.955 MHz	Upper SB & A-M Group
7.4585 MHz	1	5	9	13	17	21	7.4615 MHz
7.4685 MHz	2	6	10	14	18	22	7.4715 MHz
7.4785 MHz	3	7	11	15	19	22A	7.4815 MHz
7.4985 MHz	4	8	12	16	20	23	7.5015 MHz

OSCILLATOR TROUBLES

Unstable transmitter operation often results from improper tuning of the oscillator stage. In some circuits the load-tank inductance is varied by adjustment of its core (as in Figs. 3-6 and 3-7); in other

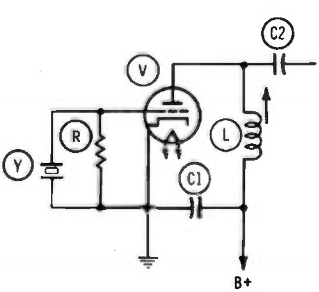


Fig. 3-6. Triode-tube oscillator with tunable output tank coil.

transmitters this inductance may be of a fixed value, and the load-tank capacitor may be adjustable. In some oscillators, as shown in Fig. 3-8, no tank coil is used.

When tuning the oscillator output circuit, the results may be noted by observing changes in transmitter output or by monitoring the voltage at the input of the rf amplifier with a vacuum-tube voltmeter connected through a high-value, series-isolating resistor or probe. The isolating resistor should be at the end of the lead so that the meter lead will not detune the circuit.

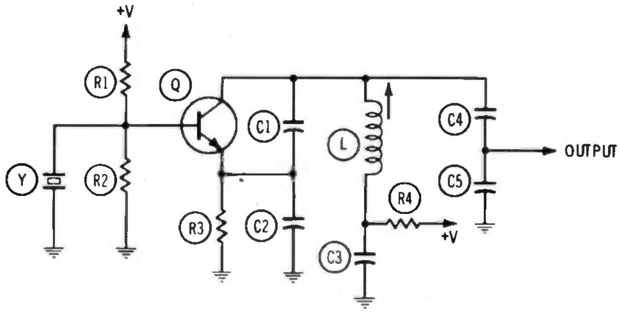


Fig. 3-7. Transistor oscillator with tunable output tank coil.

Initially, tune the variable load-tank component for maximum meter reading (resonance). The presence of voltage indicates that the oscillator is functioning, since the voltage exists only when an rf signal from the oscillator is present.

After tuning the variable load-tank component for maximum meter reading, adjust it in one direction and then the other, and note that the meter reading falls off faster in one direction than the other. Now, adjust the load tank to a point on the more gentle slope side of the maximum meter reading. This point should be below maximum, but as high as possible without loss of stability. Key the transmitter on and off when these adjustments are made until a point is reached where the meter reading appears and stays constant each time the transmitter is turned on. If set too close to maximum, the oscillator may fail to start. In a multichannel transmitter, adjustment of the load tank must be a compromise for all channels.

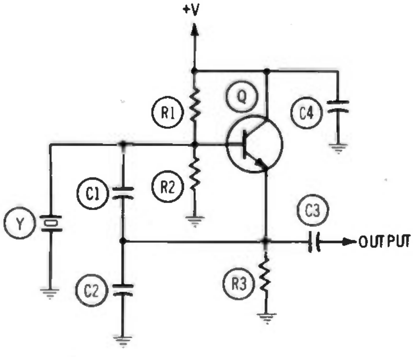


Fig. 3-8. Transistor oscillator without tunable output tank.

Defective Crystals

Unstable oscillator operation or insufficient oscillator output can be due to low crystal activity. Try a new crystal, even of another frequency. If a new crystal shows marked improvement in the oscillator, install a new crystal of appropriate frequency. Whenever installing a new crystal, measure the transmitter frequency.

Insufficient Oscillator Output

If the oscillator output is too low, there will be insufficient rf amplifier drive to secure maximum transmitter power output. Low oscillator output may be caused by a weak crystal, poor oscillator tube, or change in value of the oscillator grid-leak resistor in a tube-type transceiver.

FIXED-TUNED RECEIVERS

The frequencies of receiver crystals can be measured with an electronic counter connected to the local oscillator output. At each channel setting, measure the frequency. If any crystal is off much more than 1 kHz from its marked frequency, it should be replaced.

A quicker way is to use a 23-channel CB set as a signal generator. Loosely couple a continuously tunable frequency meter (such as a BC-221) to the i-f amplifier, as shown in Fig. 3-9. With both sets switched to the same channel and the shop set transmitting, tune the frequency meter for zero beat in the receiver speaker, or in the frequency-meter speaker or headphones. Compare the frequency-meter reading with the rated receiver i-f. Repeat for all channels when using an electronic counter.

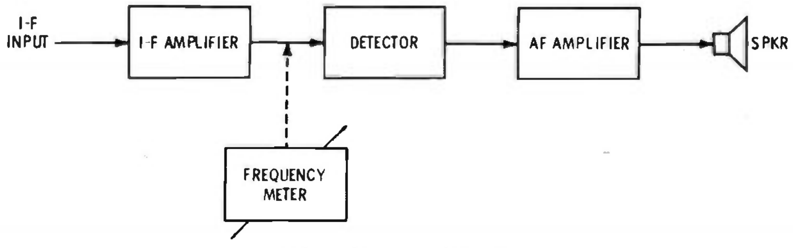


Fig. 3-9. Measuring intermediate frequency.

If the measured i-f differs widely from channel to channel (it will differ to some extent due to the crystal tolerances in each of the sets), it is an indication that the receiver crystals are not correctly matched.

In a dual-conversion, fixed-tuned receiver, one of the local oscillators is generally operated at a single frequency and the other is switched. It is important that the single-frequency oscillator be at the correct frequency since it affects all channels.

TRANSMITTER-FREQUENCY MEASUREMENT

For maximum ease and accuracy, a carrier-deviation-type frequency meter, equipped with crystals for all 23 CB channels or an electronic counter, is recommended. Connect a dummy-antenna load to the transmitter and place the frequency meter near the transmitter. The transmitter signal is picked up by a short piece of wire or a plug-in antenna connected to the frequency meter. Sometimes the frequency meter is connected directly to the transmitter through coaxial jumper cables and an attenuator. In this matter, the frequency-meter instruction book should be consulted.

Set the frequency meter and the transmitter to the channel to be measured. Turn the transmitter on and read the deviation in frequency from the correct value directly on the meter. Modulate the transmitter briefly to see if the frequency changes—it should not. Repeat this process for each channel to be checked. If any one is off more than 500 Hz (0.5 kHz), replace the appropriate transmitter crystal.

While the FCC tolerance for CB transmitters is 0.005%, or approximately 1300 Hz, you must allow for error in the frequency meter. If your frequency meter is accurate to 0.0025%, you should make a 500 Hz difference in known and unknown frequencies your standard.

Using Heterodyne Frequency Meters

You can use a surplus BC-221 frequency meter for many purposes, but it is not suitable by itself for measuring CB transmitter frequencies, except on a secondary basis. Its basic design has been utilized in more modern, more accurate heterodyne-type frequency meters that are suitable for CB frequency measurements. They are not as easy to use as difference-type frequency meters, but they are more flexible.

Connect a dummy-antenna load to the transmitter being checked. Check the calibration and allow the frequency meter to warm up as specified in its instruction book. Tune the frequency meter to the frequency to be measured, as noted in a chart or calibration curve. Turn the transmitter on and adjust the frequency meter for zero beat, as heard in its speaker or headphones (some instruments are more complex).

Note the frequency-meter dial reading, and read the measured frequency from the calibration curve. That is all there is to it; but watch out for errors in reading the dial and the calibration curve.

Quick Frequency Check

Relative transmitter frequency can be checked quickly with a calibrated, fixed-tuned, multichannel CB receiver and a calibrated i-f signal source. The CB receiver and the i-f signal source form a heterodyne frequency meter. If the receiver is of the 23-channel type, the setup shown in Fig. 3-9 can be used to check transmitters operating on any of the CB channels.

MEASURING FREQUENCY OF DISTANT STATIONS

The quick-check techniques can be used to measure frequencies of on-the-air signals by connecting the shop receiver to an antenna.

Or, you can use a shop receiver and frequency meter, loosely coupled to the receiver input, to determine the frequency of an on-the-air signal. If the frequency meter is the continuously tunable type, it is tuned to zero beat with the on-the-air signal and the frequency meter reading noted. When a crystal-controlled frequency meter (difference-type) is used, the frequency of the resulting audio beat note can be measured with an oscilloscope and an audio signal generator. The audio signal generator is tuned to the same frequency as the receiver audio output, as indicated by a 1:1 pattern on the scope screen. The frequency indicated by the audio signal generator is equal to the difference between the two signals (it should be less than 500 Hz).

FCC REQUIREMENTS

CB transmitter frequencies are measured for two purposes, to secure maximum performance and to determine if FCC regulations are being violated. When measuring transmitter frequencies, record the information obtained in case the FCC wants to know when and how the measurements were made and what the results were. In these records, "OK" is meaningless. Spell out the frequency as measured, exactly in megahertz, kilohertz, and hertz.

Although the FCC does not currently require CB licensees to have transmitter frequencies checked at regular intervals, they can demand that frequencies be checked, and they *can* take other action when off-frequency operation occurs.

The quick-check frequency-measuring techniques described here are not satisfactory for FCC record purposes since there are too many variables. A calibrated frequency meter or electronic counter of known accuracy must be used for FCC purposes.

CALIBRATING FREQUENCY METERS

A frequency meter should be calibrated at regular intervals. A precise secondary frequency standard or electronic counter can be used for this purpose. A frequency meter should be sent back to the manufacturer or to an instrument service center recommended by the manufacturer, for periodic calibration.

CHAPTER 4

Power Amplifiers and Modulators

The transmitter oscillator is always followed by one or more rf amplifier stages, since direct modulation of the oscillator can affect the oscillator frequency stability. The oscillator tank and power amplifier are tuned to the same frequency, except when a frequency multiplier or a frequency-synthesizer circuit is used.

Transmitter-functioning tests and adjustments should always be made with the CB-set antenna connector terminated into a dummy-load antenna (either directly or through a through-line rf power meter) or into an rf power meter that contains a dummy load. Transmitter performance can be measured and monitored by metering power-amplifier drive, power-amplifier plate or collector current, and/or relative rf power output. Power input to the final rf stage of a tube-type transmitter is determined by measuring the plate voltage and plate current and then multiplying the voltage times the current (in amperes). The answer is the power input in watts. In a transistor unit, collector current and voltage are measured. Some transmitters are provided with test points for making these measurements. The procedures in the service manual should be followed.

With 5-watts input, the output, as measured with an rf power meter, may range from 2 to 4 watts, depending on the efficiency of the transmitter. Pep output may be as high as 12 watts.

POWER-AMPLIFIER TROUBLES

The most common trouble in the rf power-amplifier or buffer or frequency-multiplier stage is a defective tube. The quickest method to find out whether or not you have tube trouble is to try a new tube. When a new tube is installed, retune the circuit to offset any differences in the interelectrode capacitances of the tubes. A common symptom of tube trouble is lower-than-normal power output or rapid falloff of power after turning on the transmitter.

A typical rf power-amplifier circuit is shown in Fig. 4-1. A pi network is used in the plate circuit. Improper operation can be the result of a significant change in the value of grid-leak resistor R1. Low transmitter output can be caused by low screen voltage due to leakage through C2 or an increase in the value of R2. If C2 is open, the rf amplifier may oscillate and cause unlawful emission. If C3 is open, rf energy can reach the modulator and cause distortion; if C3 is shorted, the transmitter will not operate; and if C3 is leaky, power output will be reduced. Capacitor C4, if open, will reduce or cut off transmitter output. If shorted, C4 will apply dangerous high voltage to the antenna.

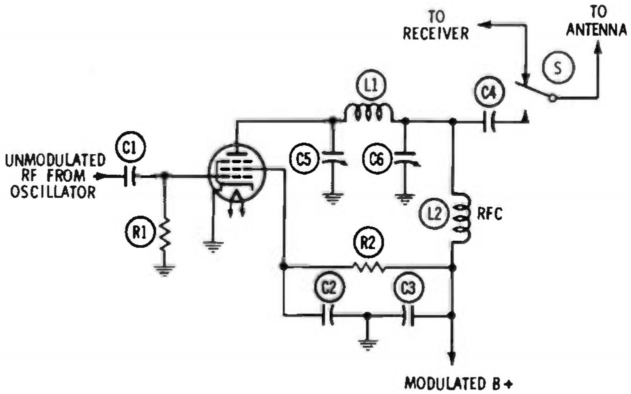


Fig. 4-1. Rf power amplifier using pi network.

If L2 is open, there will be no voltage at the rf amplifier plate; and if L1 has a shorted turn, it may absorb rf energy and reduce transmitter power. Obviously, if L1 is open or has a shorted turn, the plate-tank circuit cannot be tuned to proper resonance by adjustment of C5 and C6. Accumulation of dirt across the insulation or the plates of C5 and C6 can cause power loss due to leakage and low circuit Q. Wipe off dirt and gently blow out dust that may have accumulated on the plates.

Another source of trouble is at the antenna relay or switch (S) contacts. These contacts must be clean, and they must close firmly—never file or sandpaper these contacts. Clean them with a suitable chemical or burnishing tool. Better yet, replace the relay or switch with a new one if contact trouble is experienced.

Unstable rf-amplifier operation, such as the tendency to self-oscillate, indicates changes in component values, excessive voltages, improper lead dress, and, in some cases, improper design. Some transmitters employ a neutralizing capacitor, which must be adjusted in strict accordance with the set service manual. Whether or not a neutralizing capacitor is used, no transmitter output should be present (as noted on the rf power meter connected to the antenna terminal) when the crystal or oscillator tube is out of its socket.

Many transmitters employ the circuit shown in Fig. 4-2. The parallel-resonant plate-tank circuit (L1-C4) is inductively coupled to L2. Capacitor C5 adjusts output to the antenna. In some sets L1 is tunable. Defects in tuned-circuit components (L1, L2, C4, and C5), such as leakage, can cause improper tuning and low output power due to loss of circuit Q. Open bypass capacitors (C2 and C3) can cause self-oscillation and instability.

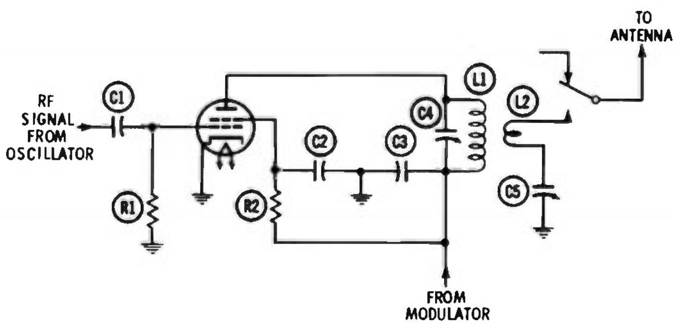


Fig. 4-2. A commonly used parallel-resonant plate circuit.

In some sets the rf amplifier tank is also used as the tuned circuit for the receiver rf amplifier or mixer, as shown in Fig. 4-3, so that trouble in the tank circuit may result in both receiver and transmitter failures.

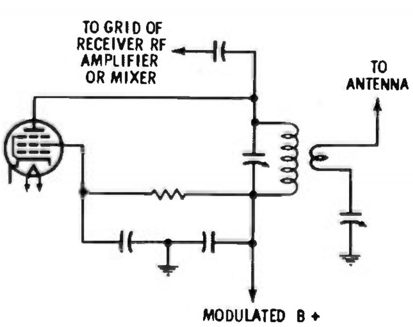


Fig. 4-3. Typical rf tank for transmitting and receiving.

The typical solid-state CB transmitter employs three rf-amplifier stages, as shown in Fig. 4-4. Transistor Q1 is the predriver, Q2 is the driver, and Q3 is the rf power amplifier. An unmodulated rf signal at the channel frequency is fed from the oscillator or frequency synthesizer to the base of Q1 through C1. Tank circuits L1-C3 and L3-C6-C7 are tuned to pass signals between 26.96 MHz and 27.26 MHz. L2 and L4 are rf choke coils. L5, L6, C11, and C12 comprise a low-pass filter and output-matching circuit; L7 and C13 form a second-harmonic wavetrap. J is the antenna socket and S represents a section of the transmit-receive relay.

In the transmit mode, steady dc collector voltage is fed to Q1 and modulated voltage is applied to both Q2 and Q3, which are biased for class-C operation.

The most common failure in an rf power-amplifier chain is blowing of output transistor Q3 by failure to connect an antenna or 50-ohm dummy load to output connector J. Transistor failure can also be caused if C4 or C6 should become shorted, causing Q2 or Q3 to have excessive forward bias.

ANTENNA SWITCHING

A switch or relay is commonly used to transfer the center conductor of the antenna transmission line from the receiver input to the transmitter output. This switch or relay generally has other contacts that cut off the speaker, disable the receiver, and activate the transmitter when transmitting. In some sets (Fig. 4-3) the antenna is connected to the transmitter and receiver at all times; it is not switched.

TRANSMITTER TUNING

The same general principles apply to tuning of all CB transmitters; however, the tuning procedures outlined in the applicable instruction book (if one is available) should be followed.

If the transmitter does not have readily accessible test points for measuring power-amplifier drive and power-amplifier plate or collector current, the transmitter can usually be tuned by connecting it to an rf power meter and dummy load. Tune the oscillator tank circuit, power-amplifier tank circuit, and antenna circuit for maximum rf power output. Then back off the oscillator tuning on the gentle-slope side (output drops off), as explained in Chapter 3. Alternately, retrim the power-amplifier tank circuit and antenna circuit for maximum power output.

Key the transmitter on and off; if the output is zero at any time that the transmitter is turned on, try retuning the oscillator tank circuit. If the power output drops off after turning on the transmitter, try new

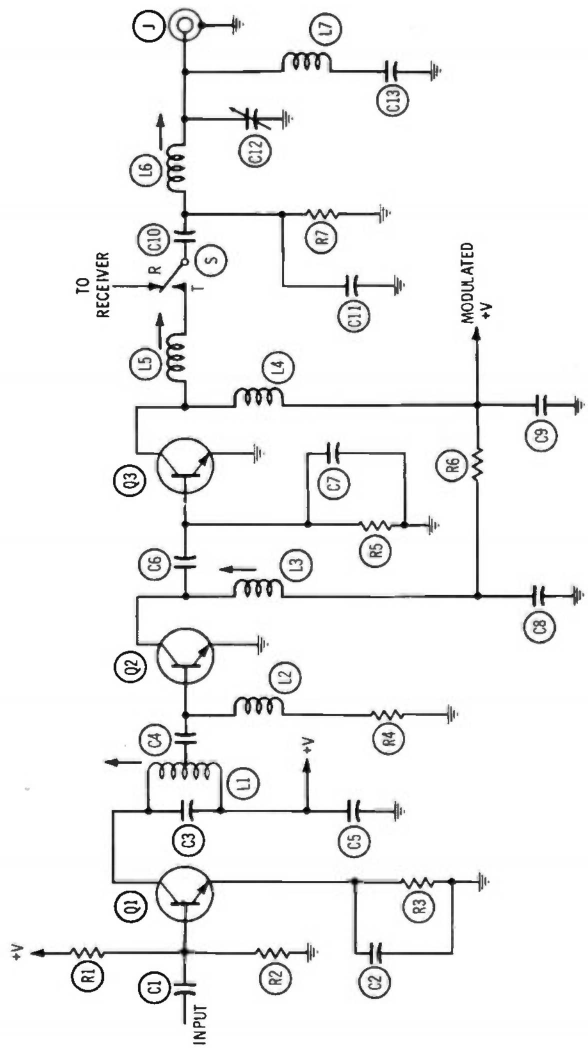


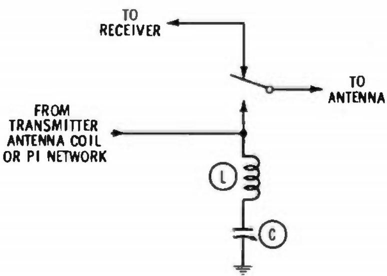
Fig. 4-4. Example of solid-state rf amplifier circuit.

tubes. Make these tests without modulation. When you talk into the microphone, transmitter power output should rise.

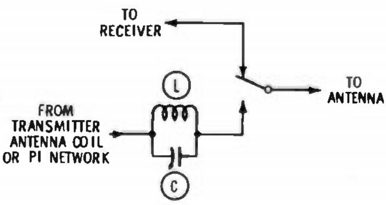
HARMONIC FILTERS

The circuits shown so far do not have the harmonic filters that are incorporated in some transmitters. When filters are not used, interference may be caused to nearby tv receivers and other radio services. The second harmonic of 27-MHz band CB channels falls squarely into one of the vhf tv channels. The fifth harmonic may interfere with aviation communications and navigation devices. The sixth harmonic falls into the 152- to 174-MHz mobile communications band.

A wave trap is used in some CB sets to suppress second-harmonic radiation. A series-resonant wave trap, shunted across the transmitter output, is shown in Fig. 4-5A. When tuned to around 54.45 MHz, it bypasses the second harmonics to ground, but has little effect on the transmitted signal in the 27-MHz band since it has a high impedance at 27 MHz.



(A) Series-resonant wave trap.



(B) Parallel-resonant wave trap.

Fig. 4-5. Wave traps.

A parallel-resonant wave trap is shown in Fig. 4-5B. When tuned to about 54.45 MHz, it presents a very high impedance to passage of second harmonics. However, the desired 27-MHz signal passes easily through the capacitor to the antenna. Wave traps of this type can be added to sets that do not have harmonic filters. Using a resonance chart, simply pick a coil and capacitor that can be tuned to resonance at any point between 53 and 55 MHz.

To tune the wave trap, pick up the second-harmonic signal (from the transmitter) with a communications receiver tunable up to 55 MHz, and adjust the wave trap for minimum S-meter indication. Or, set a tv set to channel 2 and adjust the wave trap until minimum tv interference is noted. Or, use a grid-dip meter to determine when the wave trap is resonant at about 54.4 MHz.

More-sophisticated harmonic filters are incorporated in some CB transmitters. They consist of a low-pass filter that passes frequencies below 30 MHz and suppresses higher frequencies. External harmonic filters, such as the one shown in Fig. 4-6, can be inserted in the coaxial line between the set and the antenna to suppress radiation of unwanted harmonics. Such a filter is worth trying if the customer's CB transmitter is causing interference to neighboring tv receivers.

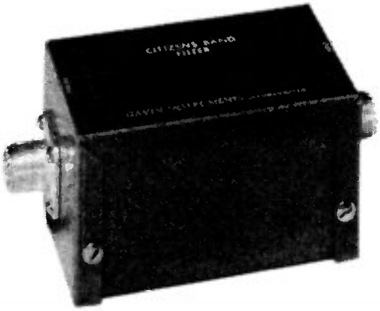


Fig. 4-6. External harmonic filter.

Courtesy Gavin Instruments, Inc.

TUBE-TYPE MODULATORS

All currently available tube-type CB transmitters employ a-m, utilizing plate or plate-screen modulation. The basic Heising modulator is used in many CB sets. The primary of the receiver audio-output transformer is used as the modulation reactor during transmission. Plate current to both the modulator tube (which also functions as the receiver af power amplifier) and the plate and screen of the rf power amplifier flows through the modulation reactor.

The circuit shown in Fig. 4-7 is typical. When transmitting, switch S1 is open to avoid the effect of speaker load on the reactance of the primary of output transformer T. Current through the primary is steady when the transmitter is on (S2 closed) and there is no modulation. The rf current leaking past the plate tank is bypassed to ground through C1 and C2. Voltage E3 across the rf amplifier is equal to E1 (source voltage) minus the small dc drop across the transformer primary.

When an audio signal is fed into V2, its plate current, flowing through the transformer primary, rises and falls with the audio signal. The large audio voltage (E2) developed across the transformer primary is alternately added to or subtracted from the voltage that reaches the plate of V1 ($E3 = E1 + E2$, when E2 is of aiding polarity, and $E3 = E1 - E2$, when E2 is of opposing polarity).

The rf power output of the rf amplifier thus rises and falls with modulation. When fully modulated, the rf output rises 50% above the unmodulated carrier level. However, with this kind of circuit, 100% modulation is not quite reached. The circuit is popular because overmodulation is inherently prevented.

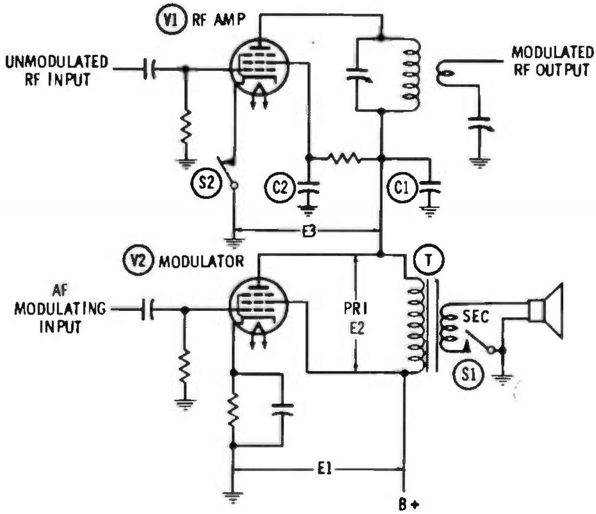


Fig. 4-7. Heising modulator.

Some CB transmitters employ a special transformer having the equivalent of three windings for achieving higher modulation percentage. The primary is tapped to form two windings connected in series-aiding (autotransformer) fashion, as shown in Fig. 4-8. The

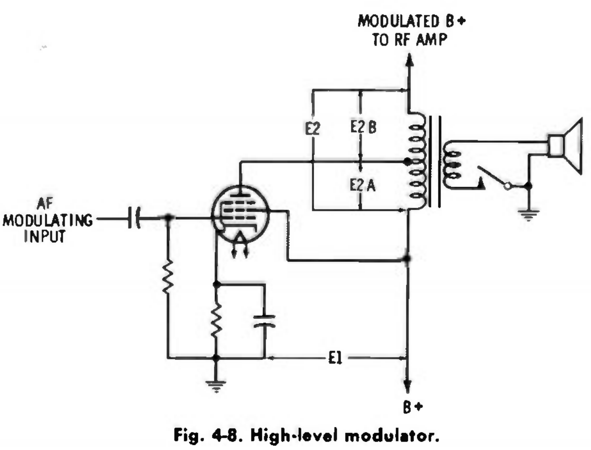


Fig. 4-8. High-level modulator.

audio signal (E2A) developed across one section of the primary induces voltage E2B in the other section of the primary. These two series-aiding voltages (E2) add to or subtract from source voltage E1, causing the rf amplifier plate and screen voltages to vary from values near zero to nearly twice E1. The entire modulator system must, of course, be designed to prevent overmodulation.

The modulator system includes a microphone, one or two stages of audio amplification, and the modulator tube and reactor. Typical is the simplified circuit shown in Fig. 4-9. When receiving, only V2 is used. When transmitting, the input of V2 is switched from the receiver volume control to the output of microphone preamplifier V1.

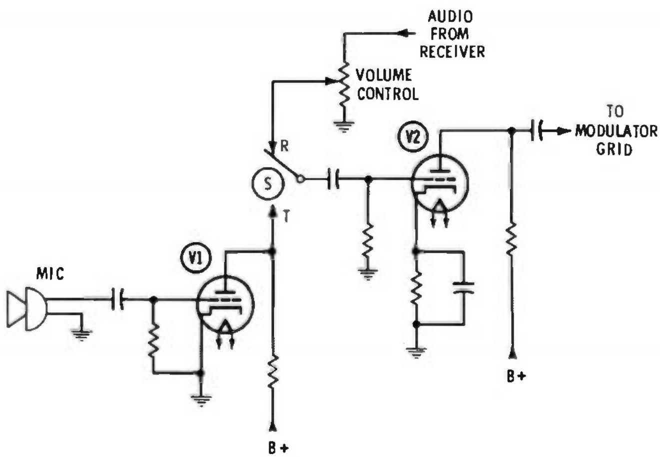


Fig. 4-9. Typical CB-transmitter speech amplifier.

SOLID-STATE MODULATORS

In the transmitter section of a solid-state CB transceiver, both the buffer and rf-output amplifier stages are amplitude modulated, as shown in the partial schematic of Fig. 4-10. (In tube-type sets, only the rf-output amplifier stage is modulated.) Modulation level may be checked by measuring rf power output with an rf wattmeter or swr meter terminated in a dummy load. The rf output should rise when you talk into the microphone. Downward modulation indicates faulty tune-up or a defective component.

Transmitter tuning is the same as for tube-type sets. Simply measure rf output with an rf wattmeter, swr meter terminated in a 50-ohm dummy load or antenna system, or field-strength meter; tune the circuits for maximum output. If a No. 47 lamp is used as a dummy load, tune for maximum lamp brilliance. Tune all circuits, except the oscillator, for maximum output. Tune the oscillator slightly below maximum output on the gentle slope of the output curve. Try the transmitter on all channels while keying the transmitter on and off several times on each channel, and note if the oscillator starts every time.

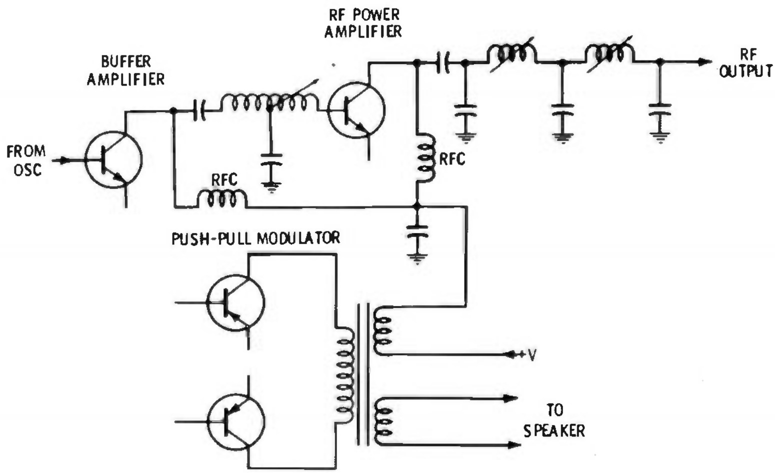


Fig. 4-10. Simplified schematic of solid-state modulation circuit.

MODULATION BOOSTER

So-called "range boosters" or "modulation boosters" are built into many CB transceivers. These circuits provide more audio gain than is actually required, plus an amplitude limiter or agc circuit that automatically limits modulator output so that 100% modulation is not exceeded. Thus, modulation is maintained at a high level when the operator speaks softly at a distance from the microphone. When the operator speaks loudly, close to the microphone, overmodulation is automatically prevented.

MICROPHONE CIRCUITS

High-impedance ceramic, dynamic, and crystal microphones are commonly used with CB sets, although low-impedance carbon microphones are used with some sets. Sometimes the receiver speaker is used as a microphone when transmitting. More audio gain is required when using one of the high-impedance microphones than when using a carbon microphone, which has much greater output. A carbon microphone requires a dc excitation voltage, whereas the other types do not.

In some sets the microphone cord is wired directly to the circuit; in others, the microphone cord is equipped with a plug, which is inserted into a microphone jack. The push-to-talk transmit-receive control switch is usually incorporated in the microphone assembly, as shown in Fig. 4-11.

Courtesy Shure

Fig. 4-11. Microphone with push-to-talk switch.

High-Impedance Inputs

Most solid-state CB transceivers are designed for use with a high-output ceramic microphone. In the example of the microphone amplifier circuit shown in Fig. 4-12, the microphone output is fed through C1 and a section of the transmit-receive relay (S) to the base of af-amplifier transistor Q1. The capacitance value of C1 limits low-frequency response, and that of C2 attenuates the higher frequencies.

This circuit was selected for discussion because its gain is automatically varied by the modulator output level. The af signal at the modulator output is rectified by diode CR. The resulting dc voltage across C6, which rises as modulator output voltage rises, reduces the forward bias of Q1 by making its emitter (through R7) more positive. When a person speaks softly at a distance from the microphone, the Q1 gain is high. When someone talks loudly, directly into the microphone, the Q1 gain is automatically reduced. This type of circuit maintains a high level of modulation and prevents overmodulation.

In the receive mode, Q2, the squelch-control transistor turns Q1 on and off as controlled by receiver agc voltage. In the transmit mode, Q2 has no effect on Q1.

Although it is not shown in Fig. 4-12, microphone cables are often equipped with a plug so that the microphone can be quickly connected and disconnected.

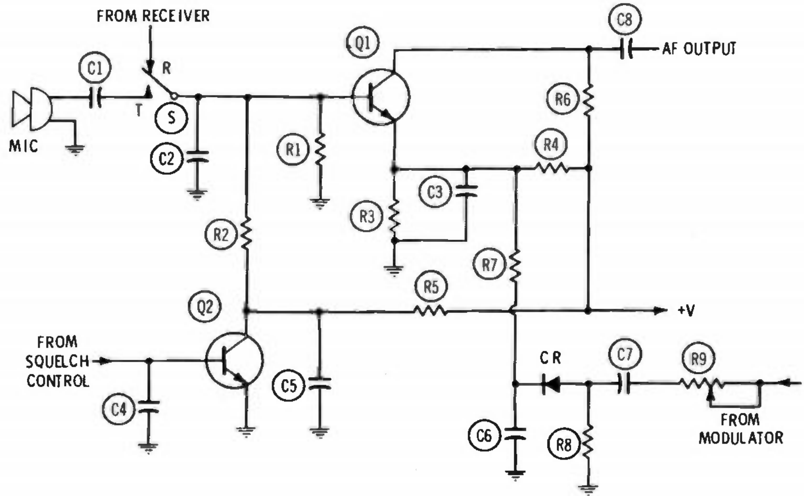


Fig. 4-12. Example of microphone circuit of solid-state transceiver.

A frequency-response compensation circuit is utilized in the Lafayette HE-20-C (Fig. 4-13). The microphone is connected to the grid of V1 through plug P1, jack J1, capacitor C1, and resistor R1. Together with shunt capacitor C2 and grid resistor R2, C1 and R1 form an RC filter. The output of the microphone preamplifier tube is also treated to adjust frequency response. Depressing the switch in

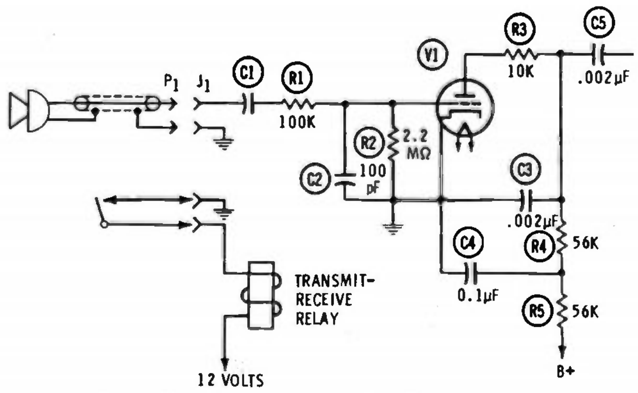


Fig. 4-13. Microphone circuit in Lafayette HE-20-C.

the microphone case energizes the transmit-receive relay, the contacts of which are not shown.

Alternate Microphone Arrangements

The microphone input circuits of CB sets must necessarily be designed to match the characteristics of the microphone that is furnished or recommended for use with the set. Frequency-compensation networks designed for one type of microphone may not be satisfactory for other types. For example, when a crystal microphone is fed into an input circuit of less than several megohms impedance, high-frequency response is enhanced and low frequencies are attenuated. Using an excessively long microphone cable with a crystal microphone can, on the other hand, cause excessive loss of high frequencies.

However, there are cases where performance can be improved by using a microphone other than that supplied with the set. Generally, high-impedance dynamic, reluctance, ceramic, and crystal microphones are interchangeable. When trying a new type of microphone, make sure that it does not overdrive the modulator and cause distortion.

If a new microphone improves the transmission of high frequencies, generally resulting in more penetrating speech, it may be necessary to add high-frequency attenuation to roll off the transmission of audio above 3000 Hz. This can be done by adding shunt capacitance across the microphone-preamplifier input and/or output. An LC filter, designed to pass voice signals below 3000 Hz, can be added ahead of or behind the microphone preamplifier. The filter must, of course, have the proper input and output impedances.

An amplified dynamic microphone contains a dynamic microphone cartridge, a transistor amplifier, and a dpst press-to-talk switch; it is equipped with a coil cord and a four-prong plug. Fig. 4-14 is a schematic diagram of the microphone assembly. Power for the amplifier is derived from the transmitter supply as shown in the diagram.

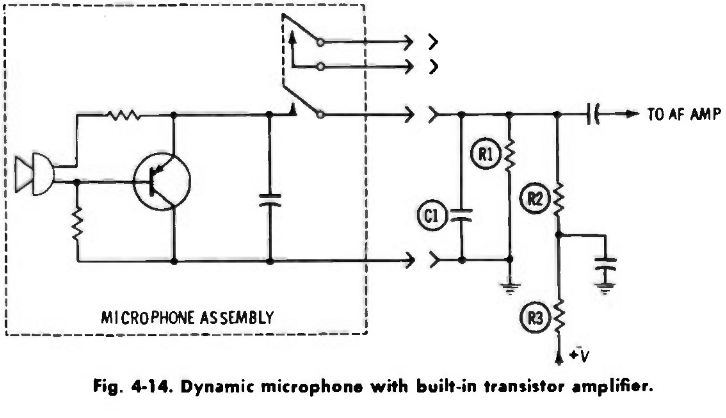


Fig. 4-14. Dynamic microphone with built-in transistor amplifier.

Handsets

Telephone-type handsets can be used with CB sets in lieu of a microphone. Handsets are available with carbon or dynamic transmitters. They are available at some radio-parts jobbers.

A handset containing a dynamic microphone (transmitter) can be connected to a CB set as shown in Fig. 4-15. A variable series resistance can be inserted in the audio-output lead for varying volume level. A cord should be used which has a shielded conductor. A regular telephone handset does not ordinarily come equipped with a cord containing a shielded conductor. Various kinds of cords are available from which a suitable type can be selected for a specific application.

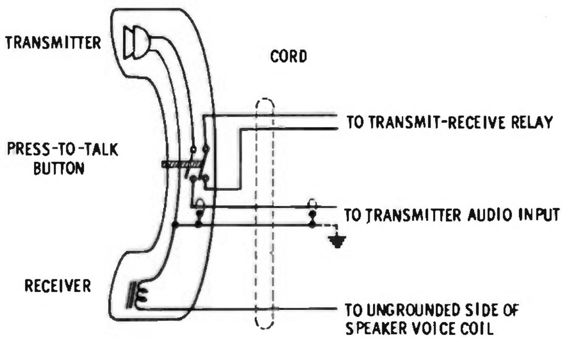


Fig. 4-15. Typical handset circuit.

MICROPHONE TROUBLES

Since a microphone is relatively inexpensive to replace, greater customer satisfaction can often be ensured by selling the customer a new microphone than by attempting to repair a defective one. Microphone repairs are best made by specialists. While test devices can be rigged up for testing microphones, the cost is seldom worth the trouble. It is much easier to substitute a new microphone and note the difference.

Defective cords and improper connections are the most common causes of microphone trouble. Some cords become stiff in cold weather, and insulation may be damaged. Extreme care should be exercised when replacing or installing microphone plugs and cords to avoid cold solder joints and shorting by strands of the shield braid. Excessive removal of the shield braid can cause annoying hum pickup. Microphone elements can become less efficient due to temperature changes, dust, and moisture. Press-to-talk switch contacts are also subject to contamination, wear, and fatigue.

Although a dynamic microphone can be checked for continuity with an ohmmeter, it is better not to make this test because of the danger of damaging the delicate cartridge. Some microphones will indicate an open circuit if checked with an ohmmeter.

MODULATION-SYSTEM TROUBLES

Effective communication range is drastically reduced if the modulation level is too low. If the transmitter is capable of overmodulation, its use is unlawful when modulated more than 100%, since it can cause harmful interference to others.

Low modulation is a very common trouble, resulting from improper tuning of the rf portion of the transmitter or a defect in the modulation system. The human voice can be used as a signal source to check modulators, but has unknown and variable characteristics. An audio signal generator should be used for making modulation-level, distortion, and frequency-response measurements (Fig. 4-16).

When connecting an audio signal generator to a CB set, the arrangement shown in Fig. 4-16A may be used. R1 and R2 form a voltage divider and a load for the generator. The value of R1 should be the same as the intended signal-generator load impedance (usually 600, 1000, or 2000 ohms), and R2 should be a 1-ohm resistor. R3 may be of almost any value between 5000 ohms and one megohm. If the signal is too small, try a resistor of smaller value for R3.

The standard test frequency is 1000 Hz. Set the signal-generator output to zero and, with the transmitter turned on (connected to a dummy-antenna load), gradually increase the generator output. Connect an oscilloscope to the output of the modulator and observe the waveform; it should be a relatively clean sine wave if the signal-generator output is a sine wave. A wave analyzer can be used to measure distortion. The actual modulated radio carrier may be observed on a scope screen, as explained in Chapter 2.

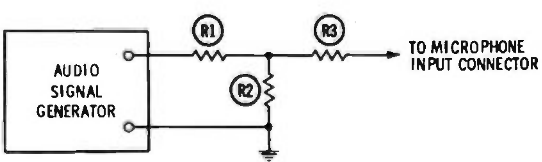


Fig. 4-16. Audio signal-generator connections.

SINGLE-SIDEBAND MODULATORS

In most a-m transmitters, modulation is applied to the rf power amplifier. In an ssb transmitter, modulation is applied ahead of the rf power amplifier. Fig. 4-17 is a simplified block diagram of the trans-

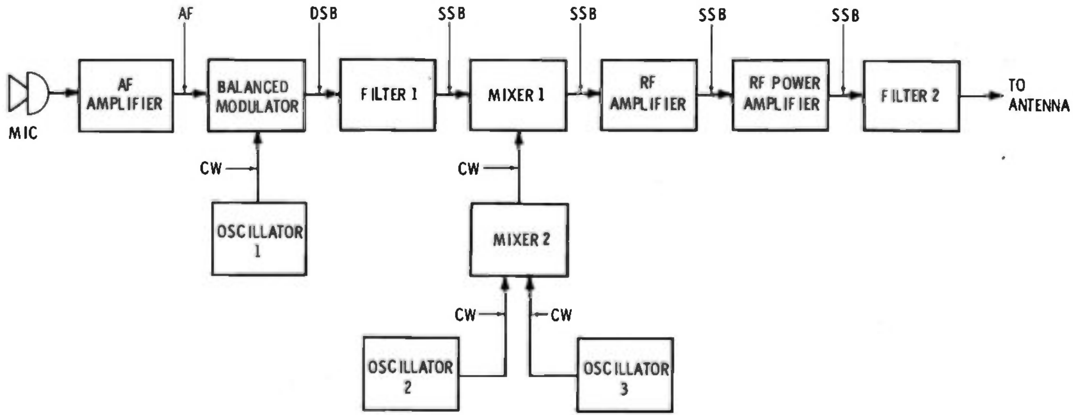


Fig. 4-17. Block diagram of an ssb receiver.

mitter section of an a-m/ssb transceiver. The af signal from the microphone is amplified and fed to one input of the balanced modulator. A cw (continuous-wave) signal from oscillator 1 is fed to the other input of the balanced modulator. These two signals are heterodyned, upper and lower sidebands are generated, and a dsb signal is present at the output of the balanced modulator. But, the carrier signal generated by oscillator 1 is missing; it was balanced out in the modulator.

The dsb signal is fed through filter 1, which passes only one of the sidebands, to mixer 1. Here the ssb signal from filter 1 is heterodyned with a cw signal from mixer 2, which up-converts the ssb signal to a CB-channel frequency. (Mixer 2 is fed by oscillators 2 and 3, which are a part of the frequency-synthesizer system.) The up-converted ssb signal is fed through a chain of rf amplifiers to the rf power amplifier; the output, in turn, is fed through low-pass filter 2, which attenuates harmonics that could cause tvi.

When modulated by a voice signal containing frequencies between 300 Hz and 3000 Hz and set for usb transmission on Channel 1, for example, the radiated sideband will extend from 26.9653 MHz to 26.968 MHz. The 26.965-MHz carrier signal is missing. When set in the a-m mode, the 26.965-MHz carrier signal and the usb signal are both transmitted. The lsb signal is not transmitted. When set in the lsb mode on Channel 1, the radiated signal will extend from 26.962 MHz to 26.9647 MHz.

An example of a balanced modulator circuit is shown in Fig. 4-18. It employs four diodes in a bridge circuit. When no modulating signal is present, but a cw signal is fed into C5, no current flows through

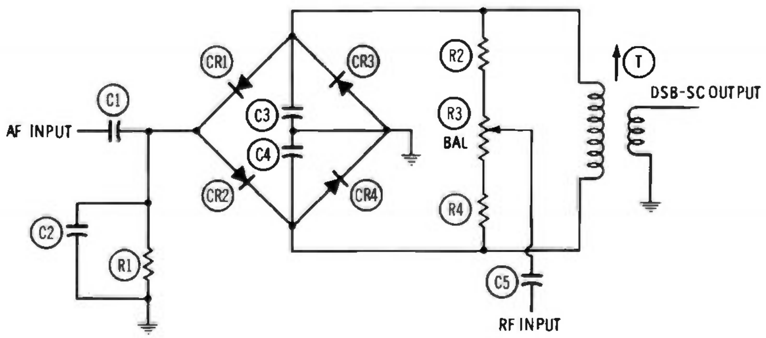


Fig. 4-18. Balanced modulator circuit.

the diodes if balance control R3 is set correctly. There is no rf signal across the primary of rf transformer T.

When audio modulation is applied through C1, a positive-going af signal will cause CR2 and CR4 to conduct and will cause CR1 and

CR3 to be switched off. A negative-going af signal will cause CR1 and CR3 to conduct and will cause CR2 and CR4 to be switched off. As a result, the af signal unbalances the bridge and amplitude-modulates the rf signal. Heterodyning action causes upper and lower sidebands to be generated. These two rf signals appear across T and are fed out to a filter that removes one of the sidebands. However, the cw-signal (carrier) that was fed into C5 does not appear at the output.

REPLACING COMPONENTS

The modulation output transformer should be replaced only with one supplied by the manufacturer of the CB set or an exact electrical duplicate when one is available. This is especially important when the design of this component is related to frequency response and to overmodulation protection. When an exact replacement is not available and the most similar part available is used, measurements should be made to determine that original performance is equalled or bettered.

Capacitors, resistors, transistors, and tubes should be replaced with like types, though not necessarily from the same manufacturer. Ceramic and silver mica capacitors, for example, should not be replaced by paper dielectric or other types, because there are electrical differences among capacitors of the same rated capacitance and voltage. The selection made by the engineer who designed the equipment is nearly always based on valid reasons. When some other type of component is used as a replacement, the equipment might no longer perform as specified.

No components of an FCC-type-accepted CB transceiver may be replaced by any other than an exact duplicate or one that has been approved by the equipment manufacturer. Using an unapproved component can result in cancellation of type acceptance.

Obtaining approved replacement components may be difficult, especially if the manufacturer is no longer in the CB equipment field or if the transceiver is an old model. Coils and transformers can be rewound if replacements are not available. Some exact replacement and substitute coils and radio transformers are available from J. W. Miller Company, and other coil manufacturers, through electronic-parts distributors.

CHAPTER 5

Selectivity and Sensitivity

A Citizens band receiver must have a great deal of gain in order to receive radio signals of only a few microvolts and deliver a watt or more of audio power. The sensitivity of a CB receiver is normally rated as the number of microvolts of signal at the antenna terminals for a specified (usually 10 dB) signal-plus-noise-to-noise ratio. If, for example, the receiver is rated at 1 microvolt for a 10-dB $s + n/n$ ratio, the audio signal output is 10 dB greater than the noise output when a modulated rf signal is applied at a level of 1 microvolt.

RECEIVER GAIN

The actual gain of the receiver is determined by the strength of the signal required to produce full-rated audio output. If a 10-microvolt radio signal is required to produce 1 watt of audio into a 3.2-ohm speaker, the voltage gain of the receiver is 179,000, the ratio of 1.79 volts (output voltage $= \sqrt{1 \text{ watt} \times 3.2 \text{ ohms}}$) to 0.00001 volt (10 microvolts). The power gain in decibels can be calculated by determining the power input, which is determined by dividing the square of the input voltage (10 microvolts squared) by the load resistance (generally 50 ohms), and then converting the ratio of output power (1 watt) and input power into dB.

This great amount of amplification is required in order to make effective use of low-power CB signals. While receivers with even greater gain can be designed, no useful purpose is served since the ambient noise level limits useful sensitivity. Under good conditions, the ambient background noise is in the order of 2 to 3 microvolts or more in the 27-MHz band.

SIGNAL LEVEL

The field intensity of a radio signal in space is expressed in microvolts per meter. The strength of a radio signal at the antenna terminals or the receiver input can be expressed in microvolts, dBμ (dB with respect to 1 microvolt) and dBm (dB with respect to 1 milliwatt of power). Their relationship is tabulated in Table 5-1. As can be seen in the table, the signal power level is −107 dBm (one 5000-billionth of 1 milliwatt), when signal voltage level is 1 microvolt (0 dBμ). When signal voltage level is 1000 microvolts (1 millivolt), power level is −47 dBm (0.5 microwatt).

When a transmitter delivers 4 watts into a 50-ohm antenna system, the voltage level is +152 dBμ (approximately 14 volts) and the power level is +36 dBm. If coaxial-cable loss is 1 dB and antenna gain is 2 dB, radiated power level will be +37 dBm (about 5 watts), the increase from 4 watts being the result of the 1-dB net gain of the antenna system. Assuming that the plane-earth transmission loss between the transmitter antenna and a distant receiving antenna is 105 dB and that the net gain of the receiving antenna is also 1 dB, the signal power level at the receiver input will be −67 dBm (+37 dBm minus 105 dB plus 1 dB), which is equal to +40 dBμ or 100 microvolts. Although a 100-microvolt signal is a very strong one, it represents a very small amount of power.

Table 5.1. Relationship of Signal Strength to dBm and dBμ. Across 50-ohm Receiver Input

Microvolts	dBm	dBμ	Microvolts	dBm	dBμ
0.5	−113	−6	50	−73	34
1	−107	0	100	−67	40
2	−101	6	500	−53	54
4	− 95	12	1000	−47	60
8	− 89	18	10,000	−27	80
10	− 87	20	100,000	− 7	100

SUPERHETERODYNE RECEIVERS

Most CB sets employ superheterodyne-type receivers to obtain the required sensitivity and high selectivity. In this type of receiver, as explained in Chapter 3, the incoming radio signal is converted to a lower frequency where it is easier to obtain gain and selectivity. Many receivers employ single-conversion superheterodyne circuits in which the signal frequency is heterodyned only once to a lower frequency.

Others utilize a dual-conversion superheterodyne circuit in which the signal frequency is heterodyned to a lower frequency in two steps. In some sophisticated communications receivers, triple conversion is used.

A superheterodyne receiver always contains at least one mixer (first detector), a local oscillator, an i-f amplifier, and a demodulator (second detector) ahead of the audio amplifier. Dual-conversion receivers employ two mixers and two local oscillators. In any type of superheterodyne receiver, one or more rf amplifier stages can precede the first mixer, and more than one i-f amplifier stage at the same frequency is often used.

ANTENNA INPUT CIRCUITS

The same antenna is generally used with a CB set for transmitting and receiving. In some sets, a relay or switch is used to connect the antenna alternately to the transmitter output and the receiver input, as shown in Fig. 5-1. The radiating element of the antenna is connected through the center conductor of the antenna transmission line (coaxial cable) to the antenna switch or relay. The coaxial-cable shield connects the antenna ground plane (or sleeve) to the CB-set chassis ground. The shield minimizes unwanted pickup of radio signals and noise by the transmission line.

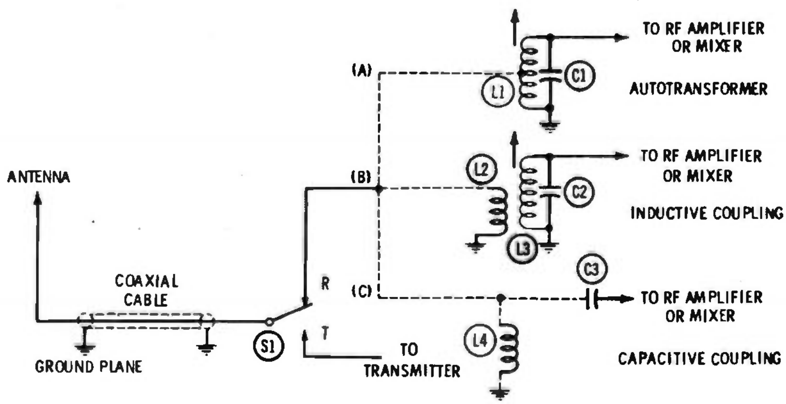


Fig. 5-1. Antenna circuits.

In Fig. 5-1, the ungrounded side of the antenna circuit may be fed to a tap of the receiver antenna coil (L1), as shown in A; to the primary winding (L2) of an antenna transformer (L2-L3), as shown in B; or through a capacitor (C3), as shown in C. In this case, the antenna circuit is usually loaded by a coil (L4).

Switchless Antenna Circuits

No antenna switch or relay is used in some transceivers. In Fig. 5-2, the incoming rf signal is developed across L1, the antenna coupling winding of the transmitter output circuit. The signal is capacitively coupled to the receiver rf amplifier through a low-value capacitor that does not significantly load down the tuned circuit L3-C3). Resistor R1 across the tuned circuit broadens the resonance and minimizes any effect the tuning of L3-C3 might have on the transmitter tank (L2-C2).

Here, avc voltage is fed through the tuned circuit, which is placed at rf ground potential by C4. Resistor R2 serves as one arm of a voltage divider that reduces the avc voltage to the desired level and limits the grid current that flows during transmission, because of the presence of the strong transmitter signal. The transmitter signal does not affect the rest of the receiver since the local-oscillator plate voltage is cut off during transmission.

A series-resonant wave trap (C1-L1) is shunted across the antenna in Fig. 5-3. It is tuned to approximately 54 MHz to reduce transmission of second harmonics, which could cause interference to nearby tv receivers. When receiving, the wave trap attenuates signals in the vicinity of 54 MHz that might desensitize the receiver.

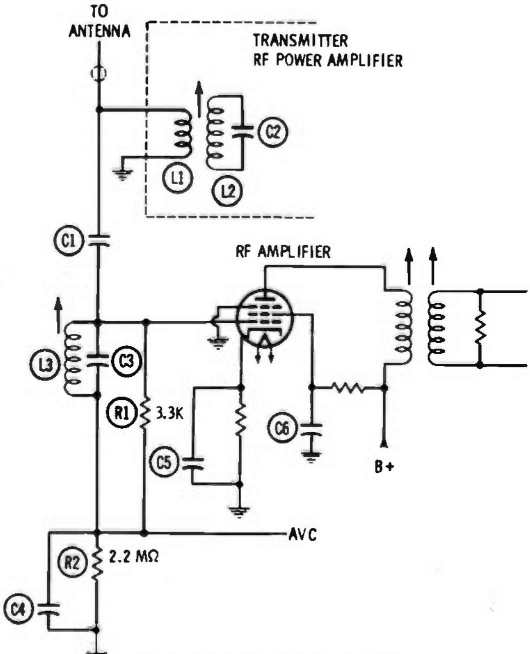


Fig. 5-2. Capacitance input.

The incoming rf signal is developed across L2 and inductively coupled to L3. The signal across L3 is capacitively coupled through C4 to the grid of the rf amplifier tube. In this circuit, L2 and L3 are shared by the transmitter and receiver.

Avc voltage is fed through R1 to the rf amplifier grid. The bottom of R1 is placed at rf ground potential by C5. In addition to avc voltage, which varies with the strength of the incoming signals, the self-bias (cathode bias) applied to the rf amplifier tube can be adjusted by sensitivity control R2.

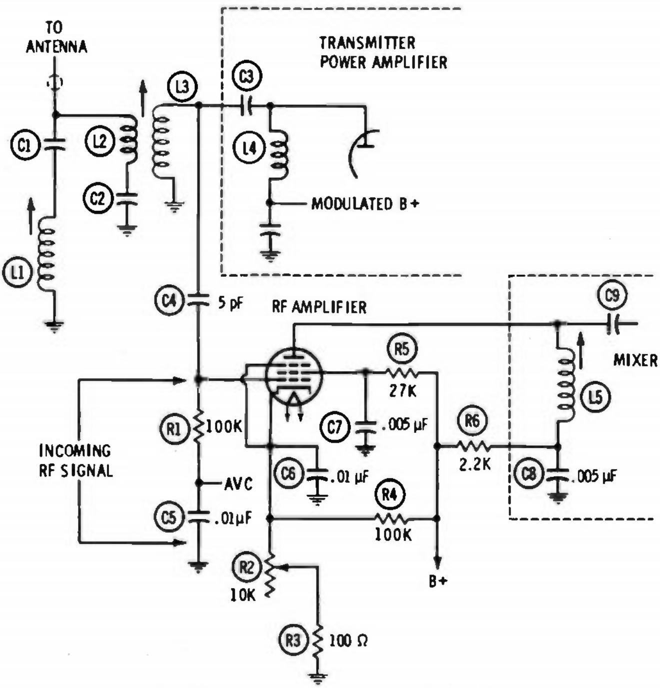


Fig. 5-3. Common transmit-receive tank.

A pi network is shared by the transmitter and receiver in the circuit shown in Fig. 5-4. In this circuit a resistor (R1) is shunted across the antenna to bleed off static charges. A series-resonant wave trap (L1-C1) is also shunted across the antenna to reduce second-harmonic emission when the transmitter section is operating.

An in-band incoming rf signal ignores the wave trap and is fed through the pi network (C2-L2-C3) to the rf amplifier tube or transistor through C6. The pi network passes the CB frequencies and also acts as an impedance matcher and as a low-pass filter that attenuates unwanted signals at frequencies above the Citizens band.

Antenna-Circuit Troubles

When a relay or switch is used to transfer the antenna from the receiver to the transmitter, troubles may be caused by dirty or defective switch or relay contacts. These contacts should be kept clean, but they should never be filed. Sufficient pressure between the contacts must be maintained. Low-tension switches or relays should be replaced.

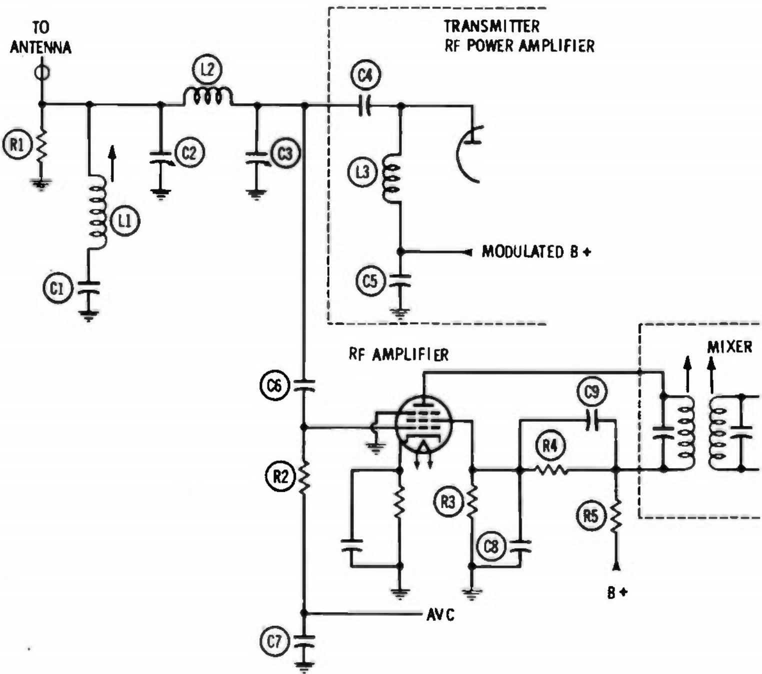


Fig. 5-4. Pi-network input.

RF AMPLIFIERS

The main purpose of an rf amplifier in a CB set is to increase the gain or sensitivity of the receiver. Its secondary purpose may be to improve the selectivity of the receiver in terms of image-signal rejection and attenuation of other out-of-band signals. In a receiver to be used for reception on one channel only, the rf amplifier may also improve selectivity in terms of rejection of adjacent-channel signals. Most CB sets are designed for multichannel operation, and the rf amplifier must be broadly tuned to favor the entire band, not sharply resonant to any particular channel frequency.

While more than one rf amplifier stage could be used ahead of the mixer, there would be little to gain in CB operations because the added sensitivity is not needed and the improved selectivity would be detrimental when multichannel operation is used. Furthermore, there is danger of overdriving the mixer and the second rf amplifier stage by strong signals. This could result in the production of unwanted modulation products.

Even when only a single rf amplifier stage is used ahead of the mixer, the circuit must be designed to minimize harmful effects that could be caused by strong adjacent signals, which the tuned circuits are not designed to reject. The chore of providing the required rejection of adjacent and co-channel signals (selectivity) is passed on to the i-f amplifier.

Most CB receivers employ an rf amplifier as the input stage. It provides gain and it also minimizes unwanted radiation of the local-oscillator signal. A remote-cutoff pentode is most often used in tube-type receivers as the rf amplifier, as shown in Figs. 5-2, 5-3 and 5-4. Some tube-type receivers employ a grounded-grid triode or a dual triode in a cascode circuit.

Most commonly used in solid-state transceivers is a bipolar transistor connected in the common-emitter configuration, as illustrated in Fig. 5-5. The diode (CR) protects the transistor from excessively strong signals. Transistor input resistance is low, but not as low as when the transistor is connected in the common-base configuration, as shown in Fig. 5-6. In this circuit, two overload diode protectors are used. Both circuits provide significant gain.

Greater use is being made of the FET (field-effect transistor), which possesses many of the characteristics of a tube but does not require high dc-operating voltage. An example of a grounded-gate FET rf amplifier circuit is shown in Fig. 5-7. The gate is grounded for rf, but not for dc, so that negative agc voltage can be applied to the gate.

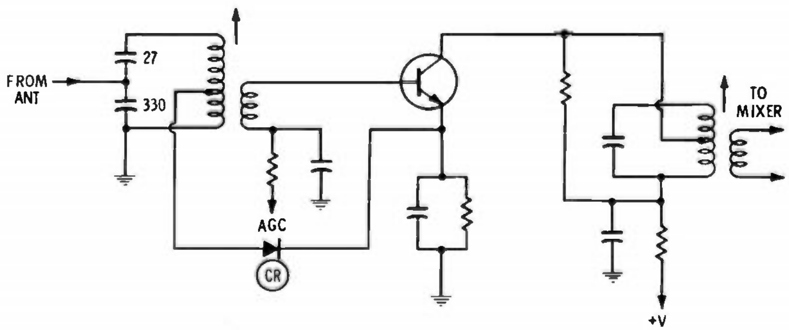


Fig. 5-5. Common-emitter rf amplifier.

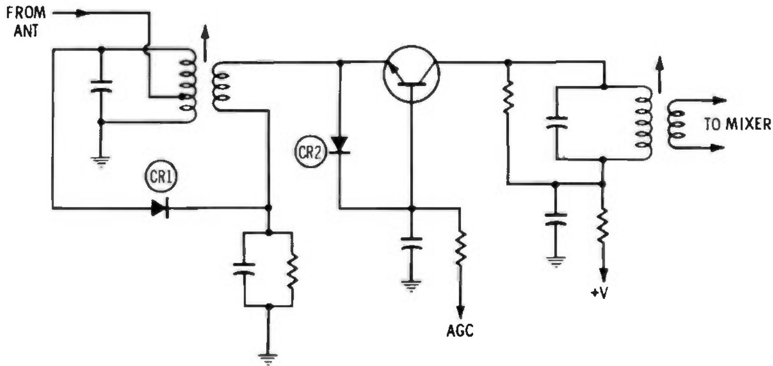


Fig. 5-6. Common-base rf amplifier.

Tuned Circuits

Because of their low cost and small size, most receivers employ slug-tuned coils, which may or may not be shunted by low-value fixed capacitors. Some sets employ fixed coils with air cores or ferrite cores; such a coil may be shunted by a variable capacitor that is the tuning adjustment.

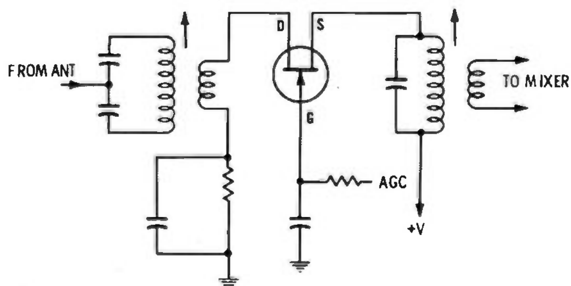


Fig. 5-7. Grounded-gate FET rf amplifier.

Rf Amplifier Troubles

When coils with tuning slugs or fixed ferrite cores are used, the core or slug may be jarred out of place by shock or vibration during shipment or use in a vehicle—this kind of trouble may be hard to trace. If adjustment of a tuning slug has practically no effect on receiver performance, look for an open capacitor across the coil (if one is used) or a misplaced core or slug. A grid-dip meter, with its coil placed close to the coil being checked, may come in handy for determining whether the coil has a shorted turn or misplaced core or slug by showing the frequency at which the coil is resonant. Sometimes the coil is used in a circuit that is not resonant in the band, and the coil serves mainly to provide a high impedance over a broad band of frequencies.

Lack of adequate gain in an rf amplifier is sometimes caused by an open bypass capacitor. Since we are working near the high end of the hf (high-frequency) band and at the border of the vhf band, capacitors used in the rf amplifier circuit should be replaced only by new ones of identical capacitance, and preferably of the same make and type. Ordinary paper tubular capacitors might have excessive inductance at these frequencies and may not be effective in bypassing unwanted signals.

MIXER CIRCUITS

Mixer is just another term for what used to be called the "first detector" when superheterodyne receivers first appeared. It is also called a *converter* or *frequency translator*. Regardless of what it is called, it is a sort of detector since it is a nonlinear device. Its output voltage is not linear with its input voltage, as is the case with Class-A amplifiers.

When two or more signals are applied simultaneously to the mixer input (biased to be nonlinear), the output composite signal contains not only signals at the input-signal frequencies, but also signals at frequencies that are equal to the sum and difference of the input signals. Other signals, such as harmonics of the input signals, may also appear at the output.

Simple Mixers

Crystal diodes are used in radar receivers and microwave communications receivers as mixers to *mix* the incoming signal with a locally generated signal to form an intermediate-frequency (i-f) signal, which can be more readily amplified than the original microwave signal. The same techniques can be used at lower frequencies.

A hypothetical circuit of a crystal mixer is shown in Fig. 5-8. The incoming signal (f_1) is passed through a filter (L1-L2-C2) that is

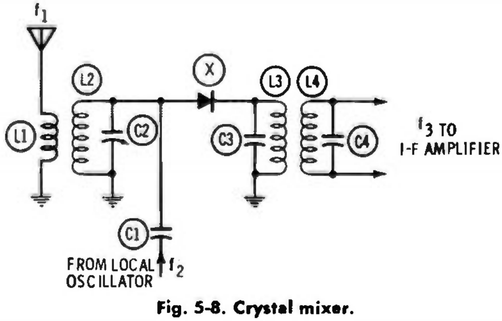


Fig. 5-8. Crystal mixer.

resonant at f_1, then is passed to the crystal diode. A locally generated signal at frequency f_2 is fed through C1 to the crystal diode. Frequencies f_1 and f_2 appear across L3-C3, but are very low in amplitude since L3-C3-L4-C4 is a filter designed to pass only one of the beat frequencies produced by mixing f_1 and f_2. If these tuned circuits are resonant to the difference between f_1 and f_2, a new frequency, f_3, equal to $f_1 - f_2$, appears across L4-C4, and all other frequencies are greatly attenuated.

Triode Mixers

A triode tube can also be used as a mixer (Fig. 5-9). The mixer triode, in this case, is operated as a grid-leak detector. Its output circuit is tuned to the desired beat frequency ($f_1 + f_2$ or $f_1 - f_2$) caused by mixing f_1 and f_2.

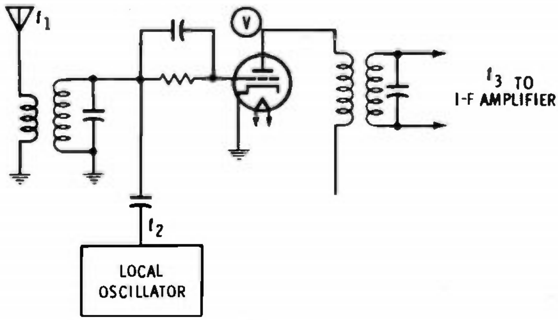


Fig. 5-9. Triode mixer.

Tetrode and Pentode Mixers

Tetrode and pentode tubes may also be used as mixers, provided they are biased (usually by the cathode resistor) as nonlinear devices.

In the pentode mixer circuit shown in Fig. 5-10, the antenna is fed directly to the mixer grid through C1. The local-oscillator signal is fed through C2 to the cathode of the tube and is developed across L1, a 30-μh rf choke that is shunted by R2. Since L1 has very low dc resistance, practically no dc cathode bias is developed.

The mixer tube is biased by the variable avc voltage, but at a lower level than the i-f amplifier. The avc voltage is cut in half by the voltage divider (R3-R4). The plate circuit is fed through 455-kHz i-f transformer T1.

A similar mixer (Fig. 5-11) employs an rf stage ahead of the mixer. Here the local-oscillator signal is fed to the mixer grid instead of the cathode. The tube bias voltage is higher than normal, and the plate and the screen are operated at reduced voltage to obtain the desired results.

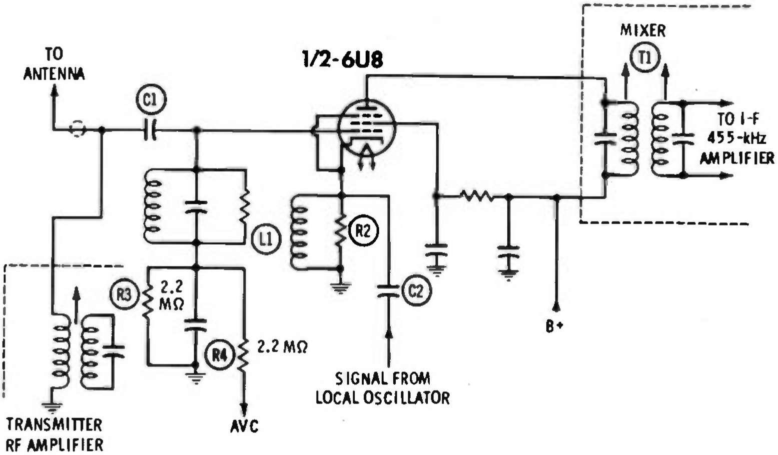


Fig. 5-10. Pentode CB mixer fed from antenna.

Both of the mixers described are used in single-conversion superheterodyne receivers. A similar circuit is used in the first mixer stage of a double-conversion receiver, as shown in Fig. 5-12. Both the received signal, from the plate of the rf amplifier, and the local-oscillator signal are capacitively coupled to the same grid of the mixer tube.

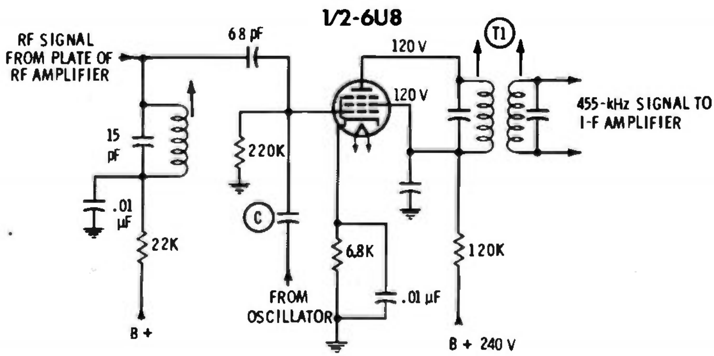


Fig. 5-11. Pentode CB mixer fed from rf amplifier.

Pentagrid Second Mixer

Pentagrid-type mixers are widely used in the second mixer stage of a circuit similar to that shown in Fig. 5-13. The rf amplifier and first mixer (not shown) are broadly tuned to the Citizens band. The first local oscillator is crystal controlled at one frequency only, 31 MHz. When the 31-MHz signal is mixed with incoming CB signals in the first mixer, the output of the mixer contains various beat signals in the 3.775-4.035-MHz range. Selection of the desired channel is made at

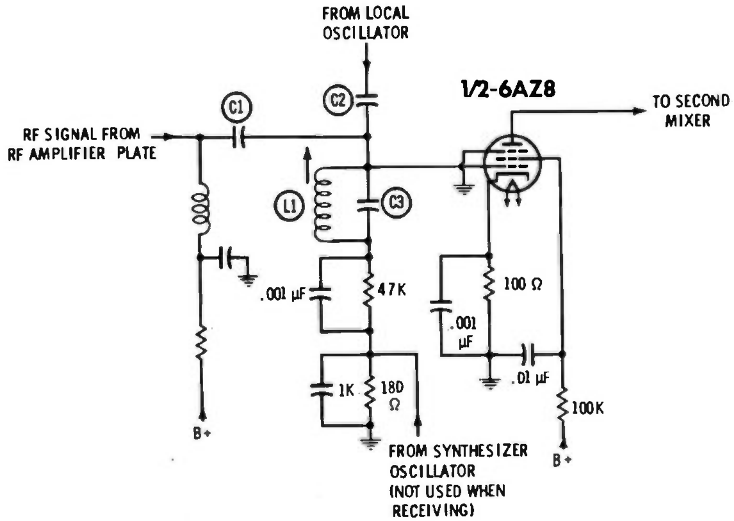


Fig. 5-12. Pentode CB first mixer.

the second mixer by means of a switch that selects any one of four coils in the self-excited second local-oscillator circuit. (Only one coil, L1, is shown in the diagram.) Each oscillator coil is tuned so that a 455-kHz beat signal is produced in the output of the second mixer only when the beat signal from the first mixer represents the desired CB channel.

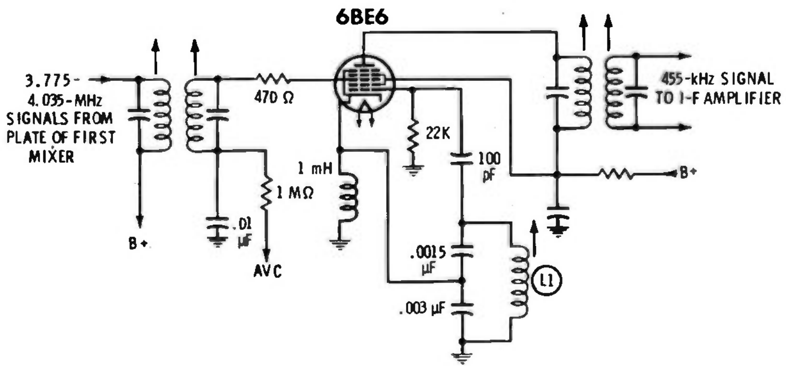


Fig. 5-13. Pentagrid second mixer with self-excited second oscillator.

Other Triode Mixers

A triode can be used in the first mixer stage of the dual-conversion receiver. As shown in Fig. 5-14, the first local-oscillator signal is fed through a capacitor to the grid of the triode along with the incoming

CB signal. The resulting 10-MHz beat signal is fed to the second mixer through a capacitively coupled bandpass filter (L1, C1, C2, C3, C4, and L2).

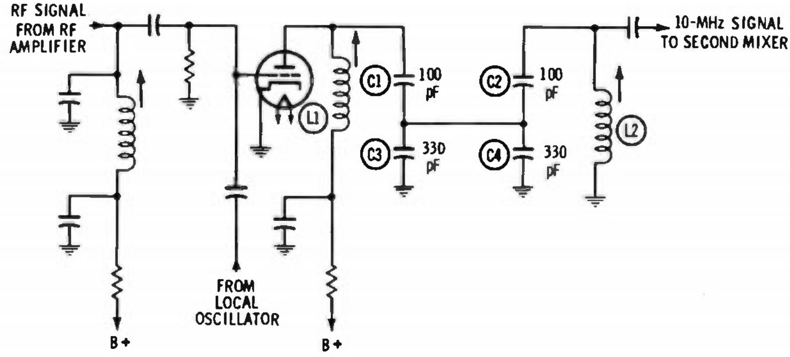


Fig. 5-14. Triode first mixer with bandpass output filter.

Two triode mixers follow one another in the transceiver of Fig. 5-15. The output of the first mixer is 10 MHz, and the output of the second mixer is 1500 kHz. The output of the third mixer (not shown), which employs a pentagrid converter tube, is at 262 kHz.

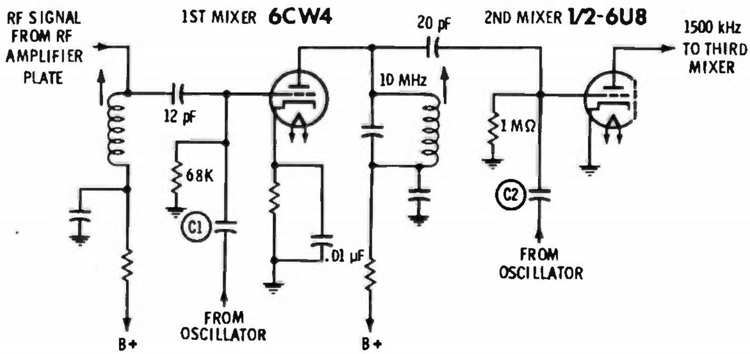


Fig. 5-15. Cascaded triode mixers.

Transistor Mixers

An example of a mixer circuit employing a bipolar transistor, connected in the common-emitter configuration, is shown in Fig. 5-16. The amplified rf signals are fed from the rf amplifier through rf transformer T1 to the base of the transistor. The local-oscillator signal is also fed to the transistor base, through C2. In some circuits, emitter resistor R4 is not bypassed by capacitor C4 and the local oscillator is capacitively or inductively coupled to the emitter.

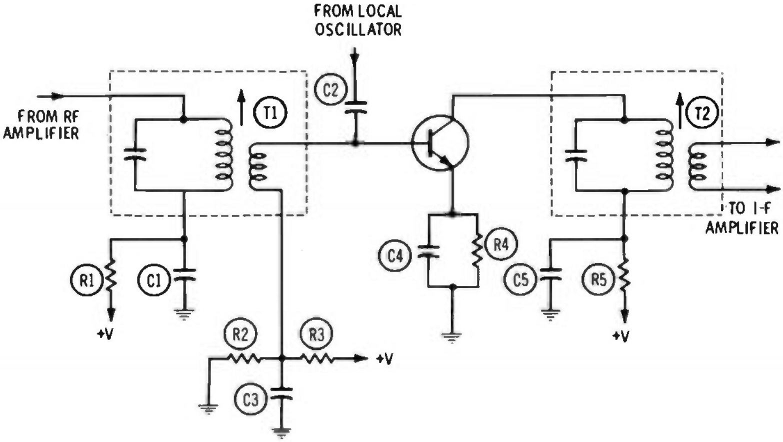


Fig. 5-16. Common-emitter mixer.

An FET is used in the mixer circuit shown in Fig. 5-17. Both the intercepted radio signals and the local-oscillator signal are fed to the gate of the FET. The required reverse bias is developed across source resistor R1. Since the input resistance of an FET is high, both windings of T1 can be parallel resonant.

In both of the circuits, T2 represents an i-f transformer to provide coupling to the i-f amplifier or to the second mixer.

The first mixer is fed many signals, since both the rf amplifier and the mixer input are broad-banded to pass signals on all channels within the 27-MHz band. The desired channel is selected and the others are rejected when the local-oscillator frequency and the desired channel

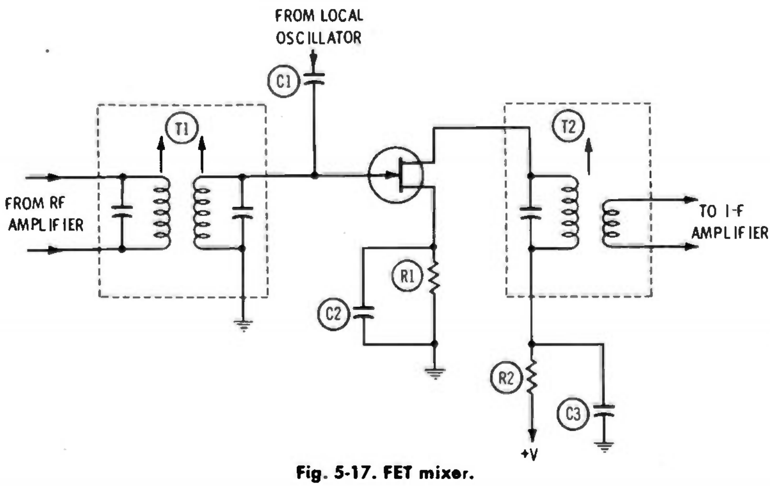


Fig. 5-17. FET mixer.

frequency are heterodyned in the mixer to generate an intermediate-frequency signal at the frequency to which T2 is tuned.

SELECTIVITY AHEAD OF THE I-F AMPLIFIER

Various types of rf amplifier and mixer circuits have been shown in order to illustrate how incoming CB signals are preamplified and heterodyned prior to high amplification at a low frequency. In all of these circuits, some selectivity, as well as voltage gain, is obtained.

The stages ahead of the final i-f amplifier introduce selectivity mainly in the form of rejection of image signals and other unwanted out-of-band signals.

Image Signals

In a single-conversion receiver with a 455-kHz i-f, signals are heard that are either 455 kHz above or below the frequency at which the local oscillator is operating. For example, if the desired signal is at 27.075 MHz, the oscillator might be operating at 26.620 MHz or 27.530 MHz. With the oscillator operating at 26.620 MHz, a receiver that normally receives signals at 27.075 MHz (27.075 MHz − 26.620 MHz = 455 kHz) may also accept incoming signals at 26.165 MHz, since a 26.165-MHz signal mixed with a 26.620-MHz signal also produces a 455-kHz i-f signal. It is the job of the rf amplifier and mixer tuning circuits to attenuate the 26.165-MHz signal and to pass the desired 27.075-MHz signal.

On the other hand, if the oscillator operates at 27.530 MHz when the receiver is set to receive on 27.075 MHz, the receiver may also pick up signals on 27.985 MHz, since mixing 27.985 MHz and 27.530 MHz also produces a 455-kHz i-f signal.

If the receiver i-f is at a higher frequency, such as 1650 kHz, the image is farther away from the Citizens band and is subject to more attenuation by the rf and mixer tuned circuits. When the local oscillator operates 1650 kHz above 27.075 MHz, for example, the image is at 30.375 MHz; when it is 1650 kHz below, the image frequency is 23.775 MHz.

By making the i-f as high as possible, image rejection is improved, but at the sacrifice of gain and in-band selectivity. In dual- and triple-conversion receivers, excellent image rejection is attained without sacrificing gain and in-band selectivity.

When image interference occurs frequently, one cure is to replace the CB set with one that has a different i-f. But, after this is done, an image signal might be present at another frequency. The elimination of image interference is relatively easy when using a single-channel receiver—change operating frequencies or add a wave trap. In multichannel operation, the problem can become rather involved.

A series-resonant wave trap may be connected across the antenna terminals (Fig. 5-3) and tuned to the frequency of the interfering signal. At its resonant frequency, the trap acts as a short circuit across the input.

Role of I-F Amplifiers

The backbone of the CB receiver is the i-f amplifier, which narrows the bandpass of the receiver so that it will give preference to a single channel and tend to reject signals on adjacent channels. Because of the narrow bandwidth and relatively low frequency, it is easy to get considerable gain using low-cost components.

Selectivity Problem

In a multichannel receiver, the rf amplifier and mixer are supposed to pass the entire 300-kHz band of frequencies in the 26.960- to 27.260-MHz range (Citizens band). Ideally, the i-f amplifier is supposed to pass a band only a little more than 8 kHz wide (two 3-kHz sidebands and two 1-kHz frequency-tolerance guard bands).

No CB receiver has a rectangular selectivity curve. Instead, the selectivity curve of a high-grade dual-conversion superheterodyne CB receiver is shown in Fig. 5-18. Its relationship to an on-frequency signal and two adjacent-channel signals of equal strength is illustrated. The curve is not a narrow line, but shifts up or down in frequency as much as 1 kHz or more because of variations in local-oscillator frequency.

The sidebands of an a-m signal contain only a part of the radiated power, so the picture is not as black as it seems. Also, a strong signal on the desired frequency reduces the sensitivity of the receiver to adjacent-channel signals because of avc action. Nevertheless, it is expected at times.

The ability of CB receivers to reject adjacent-channel signals can be improved through the use of selectivity filters ahead of or within the i-f amplifiers. Many transceivers now employ a selectivity filter. This filter may be of the mechanical, ceramic, or crystal-lattice type.

Typical I-F Amplifiers

The i-f amplifiers are essentially the same in all CB receivers. Most have two i-f stages, and nearly all employ i-f transformers with adjustable cores for tuning. A typical pentode i-f amplifier stage is shown in Fig. 5-9. Usually T1 and T2 are identical. Sometimes the i-f transformer feeding the detector is of special design. Selectivity is achieved by relatively loose coupling between i-f amplifier transformer windings, high-Q circuits, and peak tuning of all circuits. In contrast, tv and fm broadcast-receiver i-f amplifiers are intentionally broad band by design.

Whereas tubes generally have high-impedance input and output circuits, transistors normally have low-impedance inputs and outputs. For this reason, the tuned circuits in transistor i-f amplifiers are tapped or have a low-impedance winding. Fig. 5-9 shows an i-f amplifier stage employing a tube. Note that the full winding of the i-f transformer primary is utilized as the plate load and the full secondary feeds the grid of the next stage.

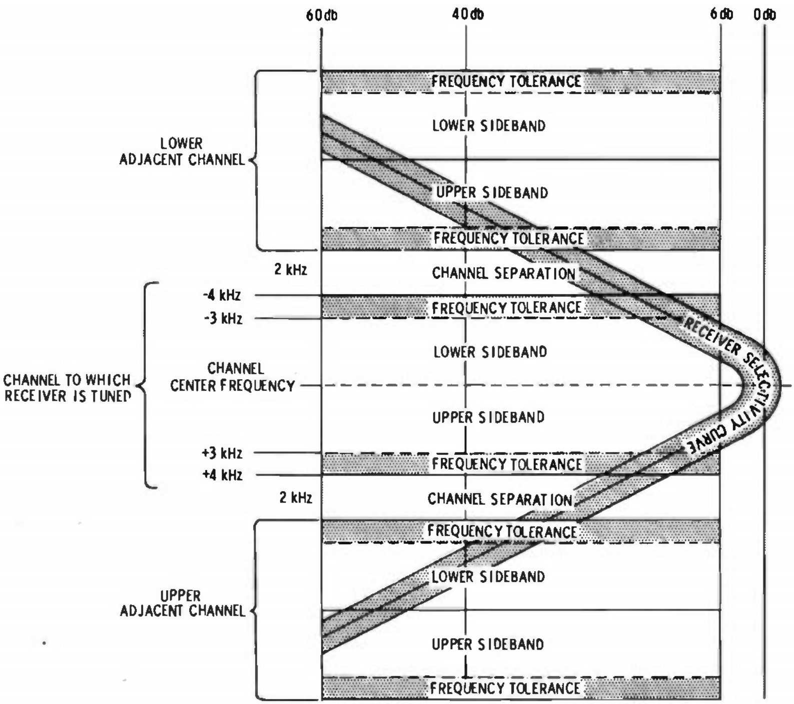


Fig. 5-18. Selectivity curve of double-conversion receiver, superimposed on three adjacent channels.

If the transistor were connected across the full winding of a parallel resonant circuit, the low impedance of the transistor would load down the circuit and lower its "Q." For this reason, only a part of the i-f transformer primary serves as the collector load in the circuit shown in Fig. 5-20, and the secondary of the i-f transformer has fewer turns and is untuned. This arrangement provides a low-impedance load for the collector of the input transistor and properly feeds the low-impedance base circuit of the second transistor; at the same time, it permits the tuned circuit to have a high "Q."

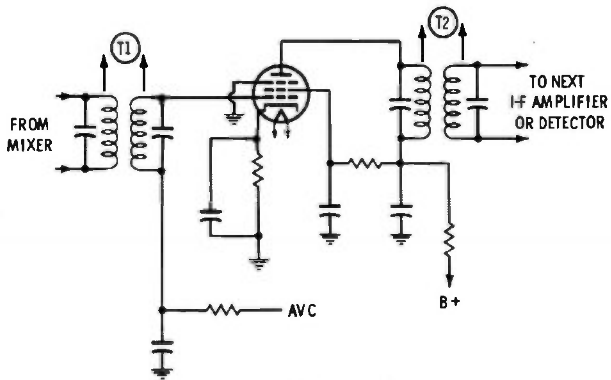


Fig. 5-19. Typical i-f amplifier stage.

I-F Amplifier Troubles

Aside from outright failure of components, i-f amplifiers are prone to self-oscillation when gain is high; this may be caused by changes in values of components and improper dressing of leads.

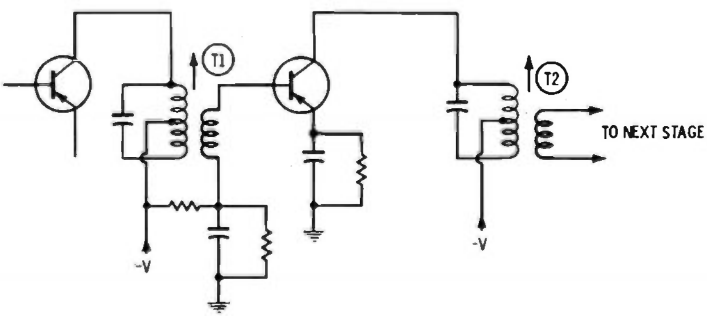


Fig. 5-20. Transistor i-f amplifier stage.

DETECTOR CIRCUITS

The detector (as differentiated from mixer stages) generally is of a type that contributes no gain. While there are detector circuits that contribute gain, they are not as practical to use as the standard diode (tube or semiconductor) detector circuit shown in Fig. 5-21. The i-f signal appearing across the secondary of i-f transformer T is applied to the diode and load resistor R1, which are in series. The diode rectifies the ac signal voltage, causing a dc voltage (polarity noted in diagram) and the audio component of the signal to develop across R1. Capacitor C1 removes any remaining rf. The audio signal is fed through C3 to the audio amplifier, generally through a noise limiter and a volume control.

The dc voltage appearing across R1 is also utilized to automatically control the gain of the receiver (avc or agc) by feeding it to the rf and i-f amplifiers. Resistor R2 isolates the avc or agc circuit from the audio circuit, and capacitor C2 prevents the avc voltage from varying with the audio signal.

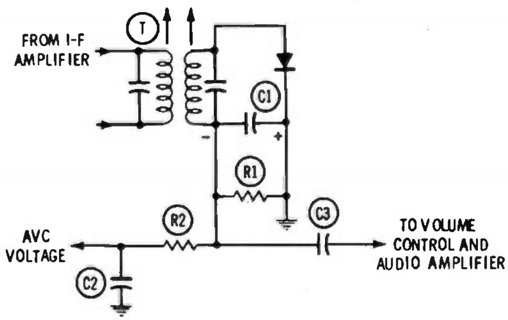


Fig. 5-21. Basic diode detector.

RECEIVER ALIGNMENT

To achieve maximum sensitivity and selectivity, the tuned circuits of the receiver must be correctly aligned with respect to each other. The procedures for aligning CB receivers are essentially the same as for other a-m superheterodyne receivers. The alignment process, unless specified in the set instruction book, is from the output to the input. That is, the i-f transformer feeding the detector is tuned first, then the preceding i-f transformer, and so on until the antenna stage is reached. The following procedure is standard for single-conversion superheterodyne receivers.

1. Connect an ac voltmeter across the speaker terminals to monitor the audio-output voltage level.
2. Disable the local oscillator by removing the receiver crystal, if this is feasible, or by setting the channel selector to an unused channel.
3. Connect the hot output lead of an rf signal generator to the plate of the mixer tube (or collector of the mixer transistor) through a small capacitor, about 10-pF capacitance (Fig. 5-22), and connect the ground lead to the set chassis.
4. Set the signal generator to produce a modulated signal at the receiver i-f (usually 455 kHz or 1650 kHz), and set the output attenuator to a very low level.
5. Increase the signal-generator output level until the tone modulation is heard in the set speaker with the receiver volume and

squelch controls "full on" and the noise limiter cut out of the circuit.

6. Set the ac voltmeter so that the audio-output level can be read easily.
7. Adjust the detector i-f transformer and then the preceding i-f transformer, or transformers, for maximum meter reading. Reduce the signal-generator output and retune the i-f transformers for maximum meter reading.

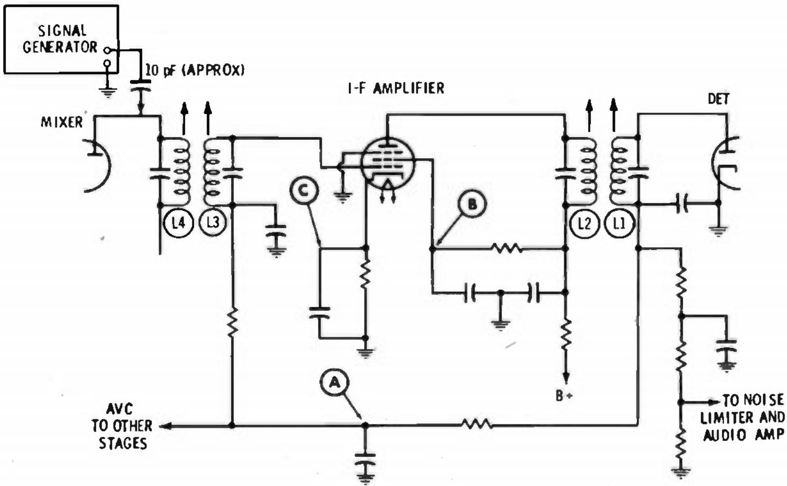


Fig. 5-22. Signal-level monitoring points in typical receiver.

8. Remove the hot signal-generator lead from the mixer, drape the lead around the mixer tube or transistor, increasing signal-generator output if necessary, and retrim the mixer output circuit. This corrects any detuning effect the signal-generator lead may have had when it was connected directly to the mixer.
9. Reactivate the local oscillator.
10. Connect the signal-generator output lead to the set antenna connector through a 51-ohm resistor (ground lead still connected to the chassis).
11. Adjust the signal generator to the receiver operating frequency (in CB band) with modulation on. Tune the signal generator slowly for maximum-output meter reading. Reduce the signal-generator output to the minimum level required to obtain a meter reading.
12. Adjust the mixer-input trimmers and rf-amplifier trimmers for maximum meter reading, reducing signal-generator output as necessary.

13. Repeat steps 11 and 12 for each channel and compromise-tune mixer and rf-amplifier trimmers in order to achieve an output-meter reading as uniform as possible on all channels.
14. Disconnect the signal generator and connect the set to an antenna. Retune the antenna trimmer only for best reception on a weak on-the-air signal, averaged for all channels, using your ear as the output monitor.

Aligning Dual-Conversion Sets

Alignment of dual-conversion superheterodyne receivers requires a few more steps. Perform Steps 1 through 8, but deactivate both local oscillators if feasible. Then reactivate the second local oscillator, apply a signal at the high i-f to the input of the first mixer, and tune up the second-mixer input circuits. Reactivate the first local oscillator and perform Steps 10 through 14.

Sometimes it is not easy to deactivate all of the local oscillators. When aligning i-f stages with local oscillators functioning, be careful not to tune up the set to a spurious signal caused by beating of various signals in the set.

Alignment Metering

While the use of an ac voltmeter to monitor audio-output voltage when aligning a receiver is easy, you can monitor avc voltage or the effects of avc voltage instead. You can connect a dc vtvm to point A in Fig. 5-22 to monitor avc voltage directly. This voltage will be negative with respect to ground, and an improvement in alignment will be indicated by an *increase* in avc voltage.

You can also connect a dc voltmeter to point B in Fig. 5-22, the screen grid of the i-f amplifier. This voltage will be positive with respect to ground, and an improvement in alignment will be indicated by an *increase* in screen voltage. A dc voltmeter connected to point C, the cathode of the i-f amplifier, will be positive with respect to ground, and an improvement in alignment will be indicated by a *decrease* in cathode voltage.

When avc, screen, or cathode voltage is monitored, an unmodulated signal can be used.

Alignment of solid-state receivers is essentially the same as for tube types. The af output voltage may be monitored when an a-m test signal is used. Or, the agc voltage may be monitored with a dc voltmeter (or vtvm or vom set to measure dc volts), as shown in Fig. 5-23.

Sensitivity Measurement

You can measure the sensitivity of a CB receiver if you have a high-grade signal generator with output attenuators that truly indicate the actual level of the output signal. Inexpensive signal generators may be equipped with calibrated attenuators, but the leakage through the case and past the attenuators can lead to erroneous conclusions.

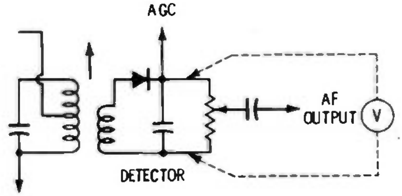
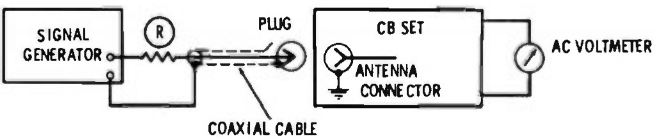


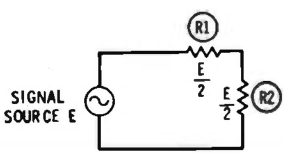
Fig. 5-23. Method of monitoring agc with dc voltmeter.

Sensitivity is measured by feeding a signal of known level to the receiver input and measuring the receiver output level. The method of connecting the signal generator to the receiver input depends on the output impedance or termination arrangements of the signal generator. A typical setup is shown in Fig. 5-24A.

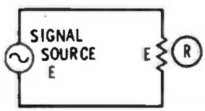
In Fig. 5-24A, the signal is fed to the CB-set antenna terminal through a piece of coaxial cable and a 51-ohm series resistor. The equivalent circuit is shown in Fig. 5-24B, where R1 represents the 51-ohm series resistor and R2 the 50-ohm receiver input impedance. The signal voltage fed to the receiver is half of the value indicated



(A) Generator connection.



(B) Effect of series resistance.



(C) No series resistance.

Fig. 5-24. Signal generator arrangements.

by the signal-generator attenuators. On the other hand, if the signal-generator output is fed directly to the receiver input, indicated as R in Fig. 5-24C, the signal voltage is the indicated full value if the proper impedance match is obtained.

To measure sensitivity, set the CB-receiver volume control for moderate volume and the squelch control wide open (noise limiter off), tune the signal generator carefully to the receiver operating frequency (in Citizens band), as indicated by maximum reading on the ac voltmeter connected across the speaker. The signal should be amplitude modulated 30% at 400 Hz or 1000 Hz. Adjust the signal-generator output to produce an audible audio tone in the speaker. Now turn the modulation on and off while adjusting the signal-generator output level. At the point where the modulated signal produces a meter reading 10-dB higher than that noted when the signal is not modulated, note the signal-generator attenuator settings. If your meter is calibrated in decibels, you can read the 10-dB difference in output levels directly.

If the signal-generator attenuators indicate that the output is 2 microvolts and there is no series resistor between the signal generator and the receiver, you can assume that the receiver sensitivity is approximately 2 microvolts for a 10-dB signal-plus-noise-to-noise ratio (s + n/n). If a series resistor is used, the attenuator will indicate 4 microvolts for 2-microvolt sensitivity.

Receiver Gain Measurement

With the apparatus connected as described, adjust the signal-generator output (modulated signal) until the output meter indicates that 1 watt of audio is being produced. If the speaker impedance is 3.2 ohms, the ac voltmeter reading should be 1.79 volts. The receiver can be said to be capable of delivering 1 watt of audio with an input signal of so many microvolts. To determine the gain of the receiver in decibels, it is necessary to convert microvolts across 50 ohms into terms of watts, which can be translated into the dB difference between input and output.

Selectivity Measurements

The same setup can be used for measuring selectivity. One way to measure relative selectivity is as follows. Tune the signal generator to the receiver operating frequency and apply a modulated signal at a level that produces 50-milliwatts audio output (0.4 volt ac across a 3.2-ohm speaker). Then double the signal-generator output voltage (6 dB) and tune it above the receiver operating frequency until the output meter again reads 50 mW (0.4 volt across 3.2 ohms), and note the frequency. Then tune it below the operating frequency until the same reference output reading is obtained and note the frequency. These are the 6-dB attenuation points, which indicate the bandwidth of the receiver.

Now advance the signal-generator output to 100 times the original voltage (40 dB) and tune the signal generator above and below the receiver operating frequency until the output reference level is the same as before. Note the frequencies. These are 40-dB attenuation points.

SQUELCH

Most CB receivers incorporate a squelch circuit. This circuit silences the speaker until a radio signal of a certain level is received. This threshold is usually adjustable. The squelch is, in a sense, a sensitivity-limiting device, and it makes the receiver more selective in terms of signal strength. Most circuits are controlled by signal level (avc or agc voltage), others by reduction in background noise due to presence of a signal.

In the squelch circuit shown in Fig. 5-25, diode V1 is normally biased so that it cannot conduct and pass audio from the detector to the af amplifier. The plate of V1 is normally less positive than the cathode, which is biased positively at a value determined by the setting of squelch control R1. The plate voltage is obtained from the screen grid of an avc-controlled rf or i-f amplifier tube (V2). When no signal, or a very weak signal, is received, the screen voltage is low since the screen draws maximum current because of low avc voltage. But, when a signal is received, the avc voltage rises, causing the screen of V2 to draw less current. The drop in R2 thus becomes smaller, and the voltage (E2) applied to the plate of V1 rises. When E2 rises above E1, diode V1 conducts and the audio signal passes through.

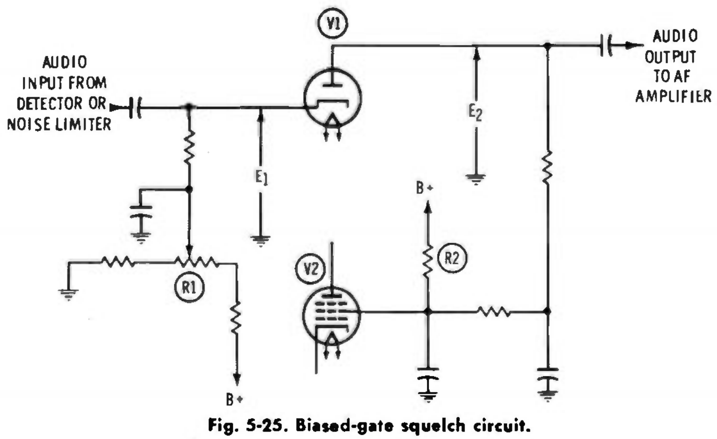


Fig. 5-25. Biased-gate squelch circuit.

The level of signal required for E2 to rise above E1 (unsquelched) is the squelch sensitivity and is determined by the setting of R1. To measure squelch sensitivity, set squelch control R1 just beyond the point at which the background noise is silenced. Then feed a signal into the receiver input (as in Fig. 5-24), and adjust the input level to the point at which the squelch "trips" and the modulated signal is heard. Note the signal level (microvolts), this is the squelch sensitivity.

An example of a transistor squelch circuit is shown in Fig. 5-26. In this circuit, transistor Q2 is an af amplifier. The af input signal is fed through C2 to the base of Q2 and the af output signal is fed out through C4. When squelched, Q2 will not allow the af signal to pass through it, and the receiver speaker is silent. When unsquelched, Q2 will amplify the af signal (or noise) fed to it through C2, and the speaker is operational.

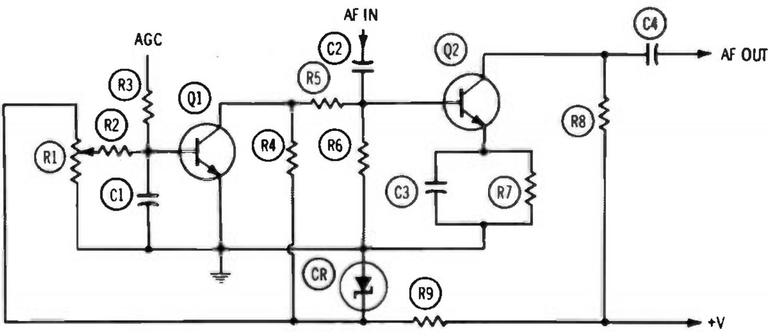


Fig. 5-26. Transistor squelch circuit.

Whether Q2 is turned on or off depends upon the state of squelch-control transistor Q1. When no radio signal is being intercepted, squelch control R1 can be adjusted to silence the speaker or to make background noise audible. To unsquelch the receiver so noise will be heard, R1 is adjusted so that Q1 forward bias will be so low that its collector current through R4 will be close to zero. Since the base-emitter voltage (forward bias) of Q2 is obtained from the junction of R5 and R6, it is governed by the voltage drop across R4. The voltage at the junction of R4 and R5 rises when Q1 collector is low, and vice versa.

To squelch the receiver (mute the speaker), R1 is adjusted to increase the Q1 forward bias and the collector current. This is done so that the voltage at the junction of R4 and R5 falls so low that the Q2 forward bias becomes very small, turning off Q2. When a radio signal is intercepted, the negative agc voltage, fed through R3 to the base of Q1, will sufficiently offset the Q1 forward bias (from R1) to cause the voltage at the junction of R4 and R5 to rise high enough that Q2 is sufficiently forward biased to turn on and allow the recovered audio signal to pass through it.

Transistor Q1 is an electronic switch that is controlled by the agc voltage and that controls the conduction of Q2. Since the agc voltage is proportionate to the level of the intercepted radio signal, R1 can be used to set the squelch-awakening sensitivity. In effect, R1 can be used to vary the sensitivity of the receiver so it will not respond to signals with a level lower than a specific level. Typically, the squelch threshold can be adjusted so that the receiver will respond to signals whose level is less than 1 microvolt or so that it will not respond unless the signal level is 30 microvolts or higher.

Since squelch response can be affected by operating-voltage variations, a zener diode (CR) is used in this circuit to stabilize Q1 collector supply voltage and base-emitter reference voltage.

NOISE LIMITERS

Nearly all CB sets are now equipped with a noise limiter between the detector and the audio amplifier, as shown in the partial schematic of Fig. 5-27. Diode X2 is normally forward biased and allows audio signals to pass through. When a noise pulse is intercepted, the diode is momentarily reverse biased, opening the audio signal path. A noise limiter reduces ignition and other impulse-type noise.

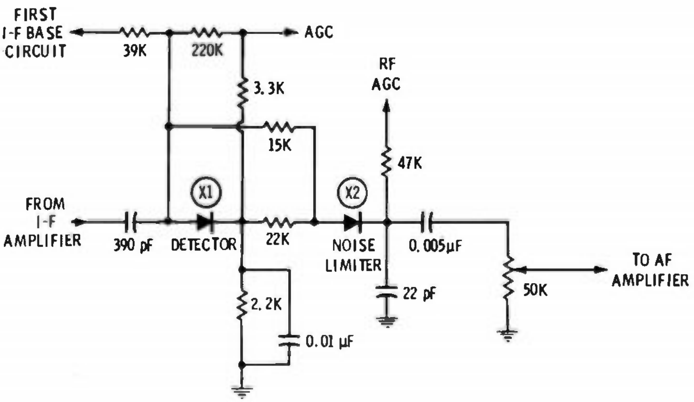


Fig. 5-27. Partial schematic showing noise limiter.

A noise blanker, sometimes called a "noise silencer," is built into some CB transceivers. It differs from a noise limiter, which is inserted between the detector and the af amplifier. A noise blanker senses off-the-air noise pulses and momentarily blocks passage of signals from the i-f amplifier to the detector. In the arrangement shown in Fig. 5-28, a separate rf amplifier picks up noise pulses, which are processed into pulses that reverse-bias the diodes in the i-f amplifier circuit in order to open the signal path for the duration of the pulses.

A popular feature is an "S" meter. In a tube-type receiver, the "S" meter usually monitors variations in the cathode voltage of an i-f amplifier stage with avc. This voltage falls off with signal strength, since cathode current is reduced by avc action as the intercepted signal rises. In a solid-state receiver, the "S" meter is usually connected to the output of the detector to measure agc voltage. The stronger the intercepted signal, the higher the agc voltage will be.

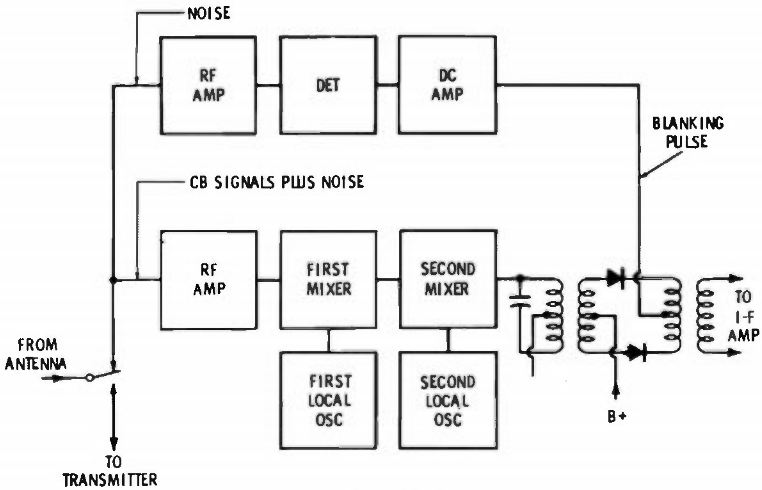


Fig. 5-28. Typical noise-blanker arrangement.

The "S" meter is also often used to indicate relative rf power output when transmitting. The rf output voltage is rectified by a diode, and the meter actually measures dc (rectified rf voltage).

INTEGRATED CIRCUITS

Many transceivers employ integrated circuits in addition to discrete transistors and diodes. A single integrated circuit (IC) can contain only a few or a great many transistors, diodes, and/or resistors in a single package, shaped like a transistor (TO-5 can) or a domino (dual in-line). Connections to the IC are made through wire leads or solder terminals.

An example of an i-f amplifier circuit employing an IC is shown in Fig. 5-29. The IC is represented by a triangular symbol. The numbers next to the leads, which are shown connected to the IC, represent the IC terminal numbers, but not their location on the actual IC with respect to each other.

A defective IC cannot be repaired; it must be replaced by one of identical type number except when an exact substitute is available.

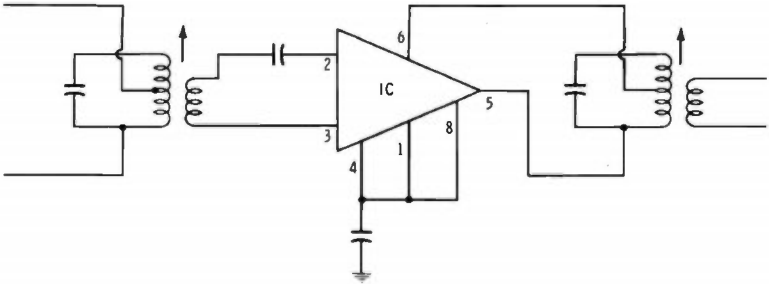


Fig. 5-29. I-f amplifier circuit employing an IC.

SSB RECEIVERS

An ssb or a-m/ssb receiver is more complex than an a-m receiver, since it contains circuitry that enables reception of the usb or the lsb and rejection of the unwanted sideband. It also contains an oscillator, which restores the carrier that was suppressed within the distant ssb transmitter. In addition, its circuitry includes a clarifier control with which the missing carrier frequency and the frequencies within the sideband are matched so that the recovered audio signal will sound natural. Since several differing techniques are used in ssb receivers, their service manuals should be consulted for circuit details.

SIGNAL TRACING

The quickest way to check the receiver portion of a solid-state CB transceiver is to use a multivibrator-type signal injector, such as the "Mosquito" (Don Bosco) or EICO PSI. Shaped like a fountain pen, this device generates a square-wave audio signal, which is rich in harmonics.

With the volume control turned up, the squelch set in the fully unsquelched position, and the transceiver turned on, touch the probe of the signal injector to the ungrounded speaker terminal and successively to the base of each transistor, from the af power amplifier back to the first rf stage. A "beep" sound should be heard in the speaker each time. If no sound is heard when the probe is touched to the transistor base in a stage, but sound is heard when the probe is touched to all stages nearer the speaker, the trouble is in that stage. However, if no sound is heard when the signal-injector probe is touched to the base of an rf amplifier stage, the trouble could be a defective local-oscillator stage or crystal.

CHAPTER 6

Power Sources

The electrical power requirements of tube-type CB unit are many times greater than either the rf output when transmitting or the af output when receiving. A typical tube-type CB set consumes 15 to 70 watts when delivering less than 4 watts rf output or when delivering 2 watts of audio into a speaker. Tube-type sets are less efficient than transistor-type sets in terms of power consumed to power delivered. A typical solid-state transceiver draws a fraction of an ampere from a 12-volt dc source when receiving, and about one ampere when transmitting.

In a tube-type set, the dc input voltage is converted into ac, which is stepped up in potential and then converted back into dc. Tube filaments are sometimes energized directly from the dc-input power source or sometimes are energized by ac from a winding on the power transformer. Transistor-type sets operate directly from the dc-input source. Hence, efficiency is higher, since there are fewer power-conversion losses.

VEHICLE POWER SOURCE

The power source in a mobile installation is the engine that drives the generator (or alternator). When the engine is running, the generator delivers electrical power. The battery is used as the power source only when the engine is not running or when the load current is greater than the generator output current. On boats, the starting battery is often the CB-set power source.

Battery Voltage

The voltage across the terminals of the vehicle battery varies widely from its 12-volt level. When fully charged, it is usually 12.6 volts, but even this is so only within a certain temperature range. On a cold day with the engine off, the battery voltage may be less than 12 volts. Depending on the voltage-regulator setting, with the engine running and the generator charging, battery voltage may rise to as high as 15 volts. Therefore, CB equipment must be designed to withstand large input-voltage variations. However, the performance is not the same at all input voltage levels—receiver sensitivity falls off and transmitter power output drops when battery voltage is lower than normal, and vice versa. Excessively high maximum battery voltage can shorten the life of CB-set components. It can sometimes cause transmitter power to rise above the 5-watt legal maximum input level or the 4-watt maximum permitted output level.

Battery Charging

In order to charge the battery, it is necessary to apply a charging voltage across it which is higher than the battery voltage. When switch S in Fig. 6-1A is open, battery voltage E1 is lower than generator voltage E2. When S is closed, E1 rises to the same level as E2, and current flows through the battery in an opposite-to-normal direction. The switch can be replaced by a diode, as shown in Fig. 6-1B. The diode allows charging current to flow when E2 is greater than E1, but it prevents current flow when the generator is not running or when E2 is smaller than E1.

(A) Switch in circuit. (B) Diode in circuit.

Fig. 6-1. Battery-charging principles.

The battery system of an auto usually consists of a 12-volt lead-acid storage battery, a dc generator driven by the vehicle engine, and a regulator. The regulator automatically connects the generator to the battery when the engine is running, and the generator voltage is higher than the battery voltage. It also prevents generator voltage from rising above a preset, safe level at high engine speeds, and it limits current flow to prevent damaging the battery or the generator.

Alternator

Alternators are now used in most cars in lieu of a dc generator. A typical system is shown in Fig. 6-2. The alternator produces three-phase ac, and the frequency varies with engine speed, which is converted into dc by a solid-state rectifier system. While the alternator and rectifier are of modern design, having no high-current moving contacts, regulators used with some of them still employ the traditional vibrating contacts. Many newer-model cars employ solid-state circuits.

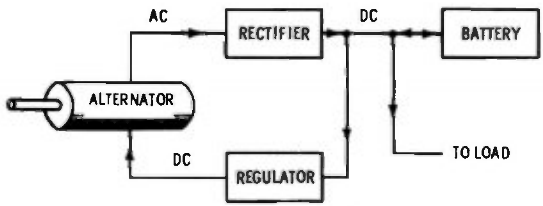


Fig. 6-2. Alternator charging system.

Regulator

The level to which battery voltage rises with the engine running is determined by the regulator. Adjustments can be made to the regulator to set the maximum voltage level. This adjustment should be made only by an auto mechanic who has had the required training and experience, and should not be attempted by a radio specialist.

The battery voltage can be checked by the radio specialist to determine if regulator adjustment or replacement is required. The voltage can be measured by simply connecting a dc voltmeter across the battery terminals and noting the voltage with the engine turned off as well as with the engine running.

MEASURING BATTERY-VOLTAGE VARIATIONS

A much more meaningful measurement can be made by using the meter-expander circuit shown in Fig. 6-3. In this device, a 12-volt transistor dry battery is connected in series with the voltmeter. The dry-battery polarity is in opposition to the storage-battery polarity, as shown in the diagram. The meter measures the difference in potential of the two batteries. If the storage-battery potential (E1) is 12 volts and the dry-battery potential (E2) is also 12 volts, the difference in potential (E3) is zero. Hence, the meter will indicate zero.

When E1 is 12.6 volts and E2 is 12 volts, the meter reading (E3) will be 0.6 volt. With the engine running, if E1 rises to 14.4 volts, the meter will read 2.4 volts. If the dc voltmeter is set to its 0- to 3-volt scale, the change in battery voltage from engine-off condition to engine running at various speeds can be read more accurately than if the same changes are read on the 0- to 15-volt scale of a conventional meter.

It should be noted that the potential across the dry battery is not always 12 volts. It may be slightly higher or lower, depending on the

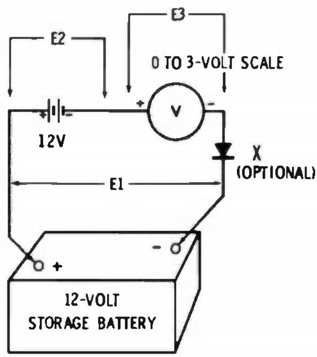


Fig. 6-3. Method for checking variations in battery voltage.

condition of the battery. But the range of voltage difference is nevertheless more easily read using the meter-expander circuit. Diode X, shown in the diagram, can be omitted; its sole purpose is to prevent backward current through the meter.

AC POWER SOURCES

Except in rare instances, 60-hertz alternating-current electrical power is available almost everywhere in the United States. There are still areas in some cities, and in some hotels and hospitals, where direct-current electrical power is used.

The ac line voltage is nominally 120 volts, but it may be higher or lower. For this reason, much electrical equipment is designed to operate safely when line voltage is anywhere in the 105- to 130-volt range. A Citizens-band set operated at 105 volts input may not perform satisfactorily. If it is operated at 130 volts input, the FCC output-power limit may be exceeded, and tube and component life may be impaired. Where line voltage is either excessively low or excessively high, a voltage-adjusting transformer, such as the Acme Type T10306 or Ohmite Type VT2F, can be used to provide the desired 120 volts.

Where the line voltage varies widely, an automatic voltage regulator, such as Sola Type 23-13-060 or Raytheon Type RVA-60, can be used between the CB set and the power line. Both of these regulators are rated at 60 volt-amperes capacity, which is generally adequate. If the CB set consumes more power, a higher-capacity regulator is required.

CB POWER SUPPLIES

Early CB transceivers employed tubes in all circuits except the power supplies of mobile units. In these units, a vibrator or a pair of switching transistors were used to covert dc into ac.

Tubes require filament (heater) voltage at 6.3 or 12.6 volts ac or dc, and relatively high-voltage dc (100 to 300 volts) is required for plates and screens. Transistors, on the other hand, operate directly from a 12-volt dc source. Mobile units obtain the required low dc voltage from the vehicle electrical system. Base-station units obtain low-voltage dc from an ac power supply in which the 120-volt ac line voltage is stepped down and rectified.

CB sets are available with integral power supplies that enable direct operation of the set in one of the following combinations: 6 volts dc only, 12 volts dc only, 120 volts ac only, 6/12 volts dc, 6 volts dc/120 volts ac, 12 volts dc/120 volts ac, and 6/12 volts dc/120 volts ac. Sets designed for operation from 12 volts dc only can be operated from a 120-volt ac source by the addition of an adapter that steps down and rectifies the voltage.

AC Power Supplies

In a basic 120-volt ac power-supply circuit of a tube-type CB set, the ac voltage fed into the primary of the power transformer is stepped down by one secondary to 6.3 volts or 12.6 volts ac for operation of tube filaments. The 120 volts of ac is stepped up by another secondary winding to obtain high-voltage ac, which is rectified, filtered, and applied to the plates and screen of the tubes.

In this circuit a vacuum-tube rectifier may be used; however, silicon diodes are used in many sets instead of a rectifier tube. A full-wave, vacuum-tube rectifier is shown in Fig. 6-4A, and a silicon-rectifier voltage doubler is shown in Fig. 6-4B.

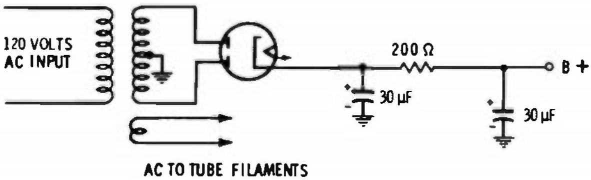
When a solid-state mobile unit is used as a base station, an ac adapter is required. It is simply a rectifier power supply which steps down the alternating-current line voltage. The reduced voltage is rectified to provide approximately direct-current voltage of 13.8 volts to the transceiver.

DC Power Supplies

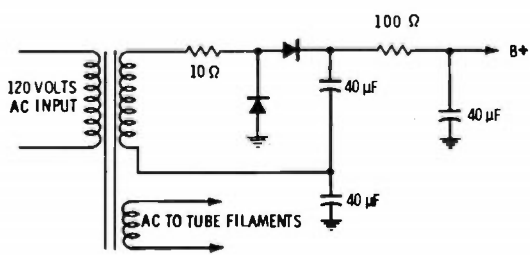
A solid-state mobile unit generally operates directly from a 12-volt dc power source; the voltage is not stepped up. The ungrounded power-input lead usually feeds power to the transceiver circuits through an LC filter, which minimizes transmission of ignition noise into the transceiver.

A solid-state mobile CB transceiver is polarity sensitive with regard to its dc power source. If the power-input leads are reversed, the transistors will be destroyed unless the transceiver has a protective circuit. In any event, it will not operate if the dc input voltage is reversed.

If the transceiver common circuits are grounded to the metal housing, either the negative or positive (usually negative) side of the supply is connected to the chassis. A transceiver designed for positive-ground vehicles cannot be used with a negative-ground electrical system, since the battery circuit will be shorted if the transceiver case touches the metal parts of the vehicle. For this reason, some solid-state CB mobile units are designed so that they can be used in a vehicle with either positive or negative ground. The common ground circuits are "floating" with respect to the metal cabinet.



(A) Full-wave tube-type rectifier circuit.



(B) Silicon-rectifier voltage-doubler circuit.

Fig. 6-4. Ac power supplies.

Some CB transceivers employ a voltage-regulator circuit, which prevents power output and sensitivity from following variations of the dc input voltage. In a 12-volt vehicle, the battery terminal voltage can vary from 11 volts (cold weather) to 15 volts (usually not over 14.5 volts) with the engine running. If regulation is not provided, power output and sensitivity will be reduced when the battery voltage is low.

In tube-type mobile units, the dc input voltage must first be converted into ac in order to obtain high dc voltages. A dc power-supply block diagram is shown in Fig. 6-5. The dc-to-ac inverter may be a vibrator (Fig. 6-6A) or a pair of transistors (Fig. 6-6B).

Vibrators—The vibrator is similar to a buzzer or doorbell. It is a high-speed electromechanical chopper or switch that alternately allows current to flow through one half of the power-transformer primary and then the other half. This causes the direction of the current to reverse alternately.

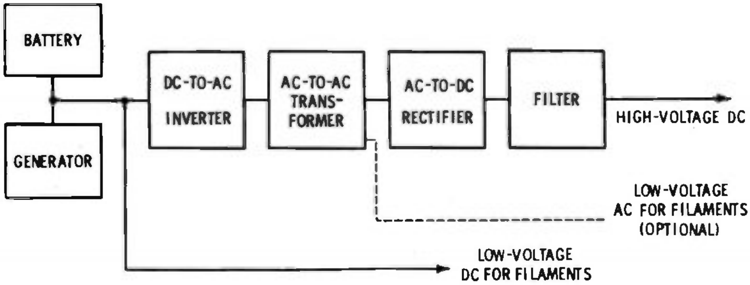


Fig. 6-5. Block diagram of dc power supply.

In each half of the primary the flow of current and the cessation of current flow causes a magnetic field that alternately reverses in direction to envelop the secondary winding(s). Hence, an ac voltage appears across the secondary winding(s). This ac voltage is not a true sine wave, as is the case in an ac power supply. The transient impulses caused by the abrupt switching of the primary are erased by a buffer capacitor, which also tends to smooth out the ac waveform.

Switching Transistors—Transistors are often used in lieu of a vibrator to switch primary current. They are used in an oscillator circuit in which one transistor conducts while the other is cut off, and vice versa. In effect, the transistors act as switches, but they have no moving contacts.

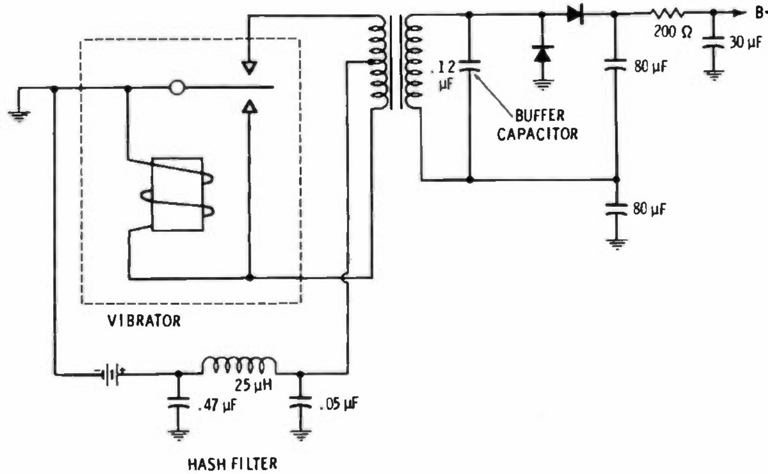
Vibrators versus Transistors—Vibrators are no longer widely used, although a plug-in vibrator can be replaced quickly, whereas power transistors are generally soldered into the circuit.

Transistor power supplies generally operate at a much higher frequency than vibrators because the speed of the power supply is limited by mechanical considerations. Because of higher frequency, a smaller and lighter power transformer is used, and ripple filtering is easier. The transistors must have heat sinks and adequate ventilation.

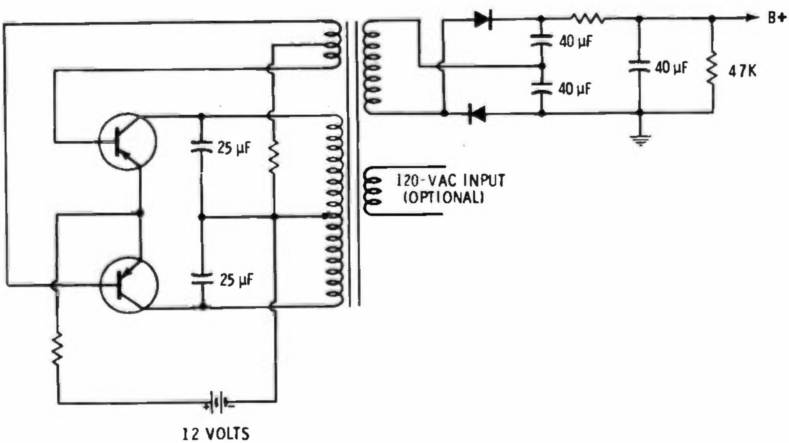
Rectifiers and Filters—The same types of rectifiers and filters are used in power supplies that operate from dc or ac. They do not greatly differ among dc-only or ac-only power supplies. With operation from dc, special design precautions may have to be taken to eliminate vibrator hash, which is not present with operation from ac.

AC/DC Power Supplies

The power-supply circuit shown in Fig. 6-7 is designed to permit operation from either 12 volts dc or 120 volts ac. The power trans-



(A) Vibrator-type power supply circuit.

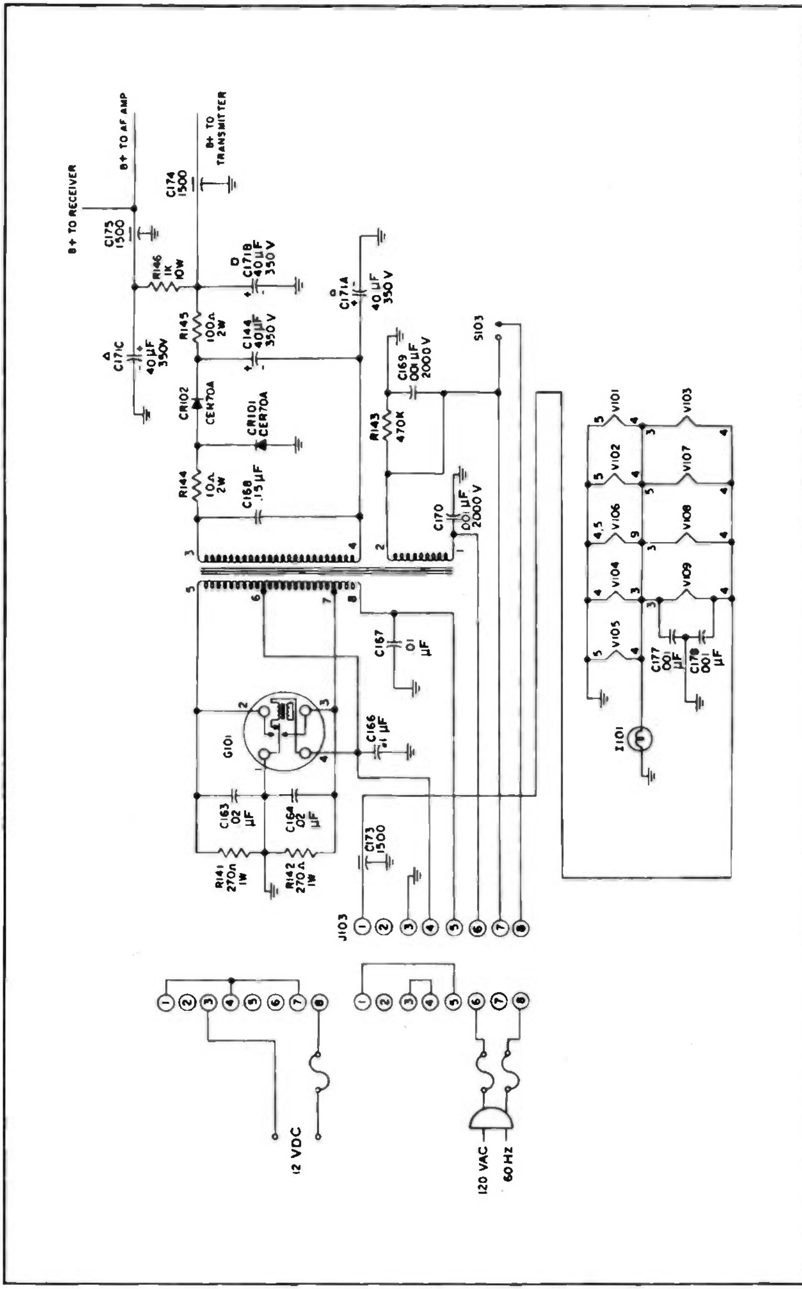


(B) Transistor power supply circuit.

Fig. 6-6. Dc power supplies.

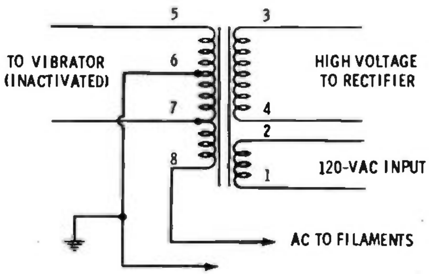
former has two primary windings, 1 and 2 for ac input and 5, 6 and 7 for dc input. When operated from ac, filament voltage is obtained from terminals 6 and 8 of the transformer, as shown in Fig. 6-8A. When operated from dc, filament voltage is obtained directly from the battery as shown in Fig. 6-8B.

The change from dc operation to ac operation is made by using a different power cable whose connector bridges the circuits, as shown in Fig. 6-7.

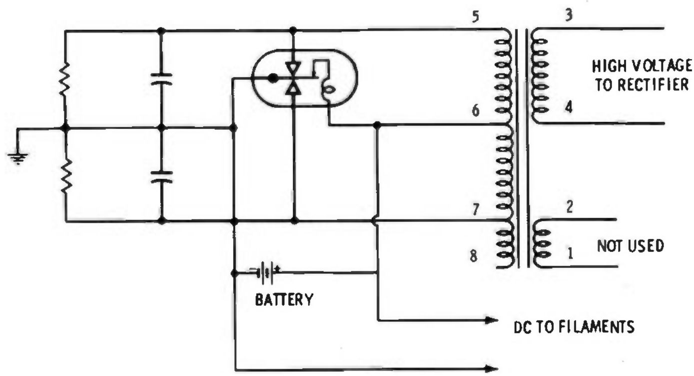


Courtesy Hammarlund Manufacturing Co.

Fig. 6-7. A 12-volt dc/115-volt ac power supply.



(A) Ac operated.



WHEN DC OPERATED, FILAMENTS ARE ENERGIZED BY THE BATTERY

(B) Dc operated.

Fig. 6-8. Ac/dc power supply.

DC Power Adapters

Some CB sets with integral ac power supplies can be operated from dc by adding an inboard or outboard power converter. The internal power supply circuit shown in Fig. 6-9 requires 120 volts ac at the primary terminals (BLK-BLK) of the power transformer. This is normally obtained from a 120-volt ac power line. For dc operation a 6- or 12-volt dc power supply is added to convert the low dc voltage to 120 volts ac.

The dc power-supply adaptor can be operated from 12 volts dc when wired as in Fig. 6-10A, or from 6 volts dc when wired as in Fig. 6-10B. The vibrator must be replaced with one of appropriate voltage rating when changing from one dc input voltage to another.

DC-to-AC Power Inverters

CB sets equipped with ac power supplies are sometimes operated from dc through an external dc-to-ac inverter. There are many types of dc-to-ac inverters on the market; some employ vibrators, and others

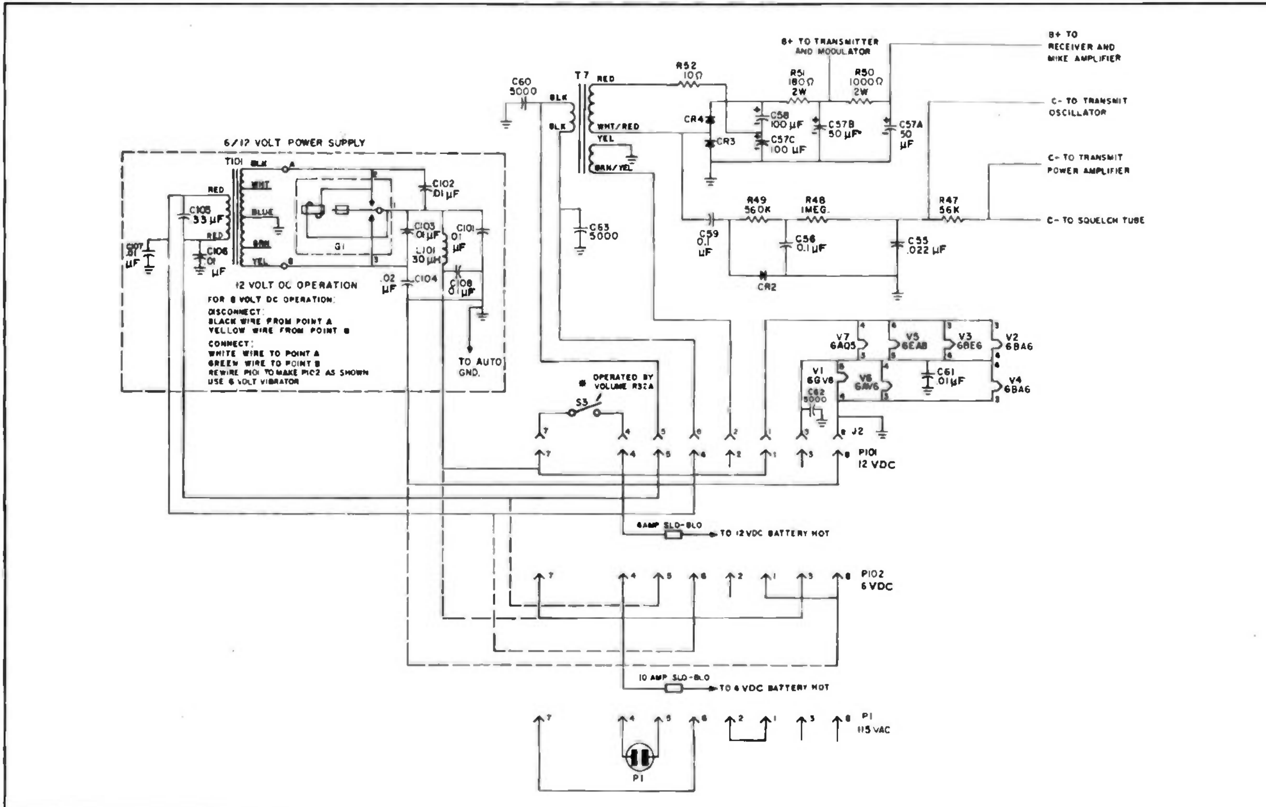
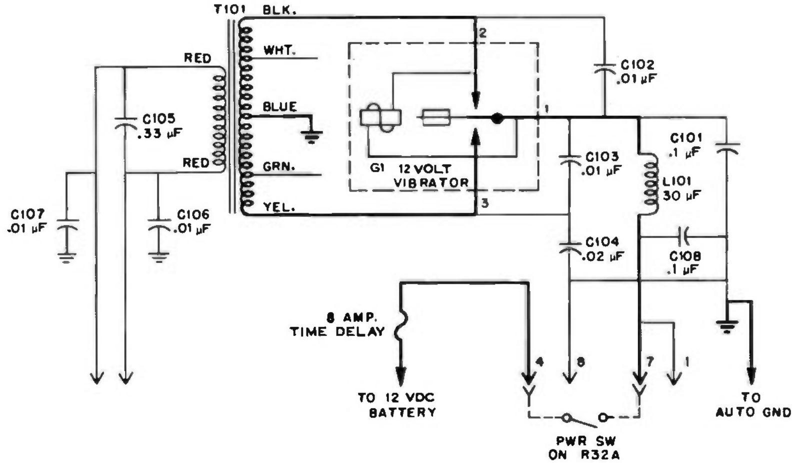


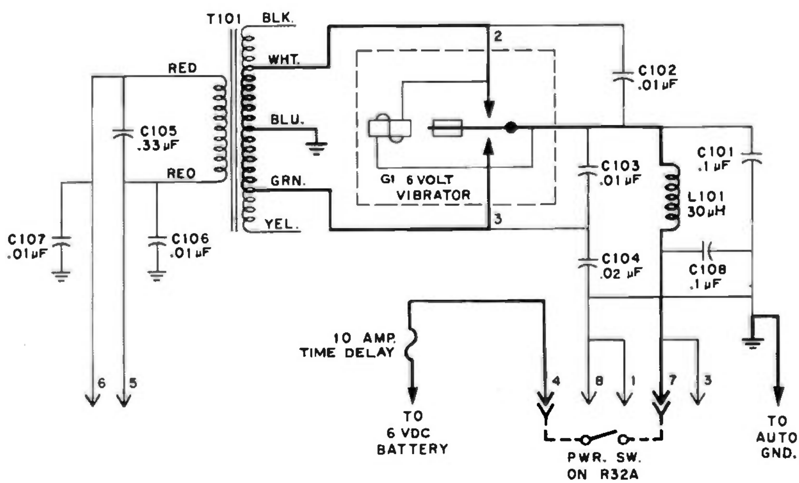
Fig. 6-9. Ac power supply with dc adapter—inside dash lines.

Courtesy RCA

employ switching transistors. When selecting an inverter, it is important to choose one that is capable of delivering adequate power on a continuous basis to avoid overheating and change in ac output voltage when switching the CB set from receive to transmit.



(A) Wired for 12-volt dc operation.



(B) Wired for 6-volt dc operation.

Courtesy RCA

Fig. 6-10. A 6/12-volt dc-to-ac power-supply adapter.

MOTOR-GENERATORS

A dropping-resistor scheme will work satisfactorily only if the current used during transmit and receive are the same. When they are not the same, a more sophisticated arrangement is required. Usually, a motor-generator or dynamotor is used. A dynamotor converts dc at one voltage level to dc at another level. It has a single armature with two windings, two commutators, and one field winding. A motor-generator, on the other hand, consists of a motor and a generator which may be two mechanically coupled machines, as shown in Fig. 6-11, or they may be combined as one machine.

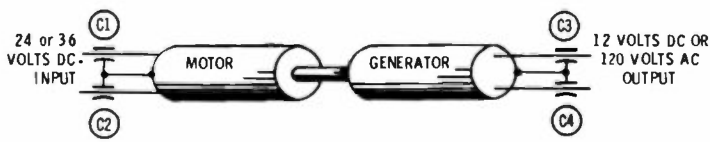


Fig. 6-11. Coaxial capacitors reduce motor-generator radio interference.

To operate an ac-type CB set from a 24- or 36-volt dc source, a dc-to-ac motor-generator (motor-alternator) or rotary converter (inverter) may be used. The machine must be designed for continuous operation from the appropriate dc voltage and deliver close to 120 volts at 60 Hz. However, when a dc-to-ac motor-generator or an engine-driven ac generator is used as the power source, the ac voltage and frequency are apt to vary. Hence, the machine should be of the regulated type with an output frequency of 60 Hz ± 3 Hz and with an output voltage held automatically to the 110- to 120-volt range.

Machine Noise

When a dc-to-dc or dc-to-ac rotating machine is used, noise interference to CB reception might be caused by sparking between brushes and commutator and by sparking at voltage- and speed-regulator contacts. This interference can be minimized or eliminated by adding appropriate filters. In some cases, standard line filters, such as those made by Miller, Cornell-Dubilier, Aerovox, and Sprague, will do the trick. However, most standard line filters are designed to suppress interference at lower than CB frequencies and may not be sufficiently effective at 27 MHz. Experimentation may be required to get rid of the noise. Coaxial capacitors, connected as shown in Fig. 6-11, might do the trick. Try various sizes of capacitors, grounding the outer sides of the capacitors to the machine frame. If these remedies are ineffective, consult the manufacturer of the machine, who undoubtedly has had experience with radio-interference problems.

Electronic Converters

Electronic dc-to-dc converters are available which permit operation of a 12-volt solid-state mobile unit from other than a 12-volt source. For example, relatively low-cost converters are available which allow operation of a 12-volt set from a 6-volt electrical source. More expensive converters are available for other input voltages. The dc input in converted into square-wave ac, which is stepped up or down in voltage and then rectified so that dc at the desired voltage is delivered.

AC POWER-SUPPLY TROUBLESHOOTING

An ac power supply of a tube-type set generally delivers high-voltage dc at one or more levels between 150 and 260 volts, and low-voltage as at 6.3 or 12.6 volts for tube filaments.

While not listed in Chapter 2 as an essential servicing tool, an ac wattmeter can be a time-saver when servicing ac-type CB sets. Fig. 6-12 is a diagram of a simple input-power measuring device. The CB set is plugged into a receptacle J, and line plug P is plugged into an ac outlet. The wattmeter may be a Simpson Model 79 with a range of 0-75 watts, or a Triplett Model 361 with a range of 0-150 watts.

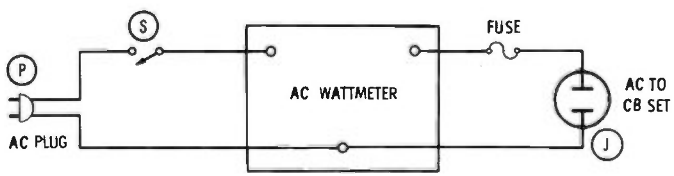


Fig. 6-12. Power-input tester.

When switch S is turned on and the CB set is turned on, the wattmeter indicates the amount of power consumed by the set. When the set is first turned on, the reading may vary as the tube filaments warm up and change in resistance and as plate currents start to flow. After the tubes have warmed up, the meter reading should stabilize and should be approximately the same as the power input specified in the instruction book. When the CB set is switched from receive to transmit, the meter reading may rise if the receive and transmit input-power requirements are not the same.

When an abnormally high power-input reading is obtained the moment the set is turned on, it indicates that there is a short circuit or an excessive leakage in the set. If the set employs a tube rectifier in the power supply, pull the tube out of its socket and note the wattmeter reading. If it remains the same (too high), the trouble is probably a short either in the power transformer, in the capacitor across the transformer high-voltage secondary (if there is one), or in the filament wiring. On the other hand, if a large drop in input-power reading occurs as the rectifier tube is warmed up and its removal causes a large drop in input power, then the trouble is probably a shorted filter or bypass capacitor. If the set employs wired-in silicon rectifiers, this kind of trouble is indicated by excessively high input power the moment the set is turned on. Therefore, be ready to turn the set off at once.

When a transceiver is set to receive, an abnormally low power-input reading, after the unit has warmed up, indicates an open circuit (open silicon rectifier, resistor, or connection) or a burned-out af power-output tube or output-transformer primary. If power input is normal on receive and too low on transmit, look for a defective rf power-amplifier tube, open connection, etc.

Variations in power-input reading, after the set has warmed up and is in the receive position, indicate erratic conditions such as leaky capacitor, defective resistor, or intermittent tube. If the variations are noted only in the transmit position, look for defective components in the circuits that are activated only when transmitting. These could include the transmit crystal. Improper transmitter tuning could also cause unstable conditions, which cause power-input variations.

A wattmeter will quickly warn you of a dangerous short-circuit condition (excessive power input). A very low power reading most often indicates that the rectifier circuit is open. Improper operation, but with normal input-power indication, points out that the trouble is of a more subtle nature and is likely to require considerable intense investigation before it is found.

DC Power-Supply Current

A dc ammeter can be used for the same purpose as the wattmeter for checking sets operated from dc when connected as shown in Fig. 6-13. Be sure to observe meter and battery polarity, and use a quick-blow fuse (less than 10-amp rating for 12-volt sets, less than 20-amp for 6-volt sets) in the circuit to protect the meter.

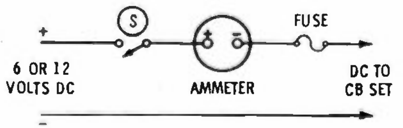


Fig. 6-13. Input-current measurement.

When a tube-type set is first turned on, the meter reading may be quite high initially due to filament inrush current. If this current remains appreciably higher than the rated current, (consult the manufacturer's instruction book), turn off the set and look for a short-circuit condition. A stuck vibrator (or shorted transistor) could be the cause. After the tubes have warmed up, current should be approximately the same as specified in the instruction book. If it is too high, look for shorts and leakage. If it is too low, look for open circuits and a burned-out tube.

Variations in current, when the CB unit is set either to transmit or receive, could be due to a faulty vibrator or an erratic buffer capacitor. If current variations are noted only in the transmit condition, look for trouble in the transmitter circuitry.

Input current to a solid-state transceiver should rise almost immediately to maximum value since transistors do not require warm-up time. When a signal (or noise)is not being received, current should usually be around 0.1 ampere, rising when a signal is received. Receive-function current does not remain constant when a Class-B audio amplifier is used. For the transmit function, current should rise to about one ampere.

Physical Observations

When a wattmeter (ac sets) or ammeter (dc sets) is not available, power-supply troubles can sometimes be sensed by smell and sight. An odor about the power transformer may be present due to a stuck vibrator or shorted transistor, or a short in the transformer, buffer capacitor, rectifier, or the circuitry beyond the rectifier. Chemical oozing from the transformer may also be present for the same reasons. A charred resistor is usually an indication of a short circuit or excessive leakage at the load side of the resistor.

Hum

Excessive hum, as heard in the speaker, is often due to an open or dehydrated filter capacitor or sometimes a shorted or leaky tube. Try a new filter capacitor of adequate voltage rating across each filter capacitor (observe capacitor polarity), one at a time, and note any change in hum level. To avoid damaging the rectifiers, start at the load end of the filter resistor (or choke) so that the capacitor will be charged before it is connected directly to the output of the rectifiers.

Hum can also be caused by a "tired" vibrator. In a set with transistors in the power supply, transistors may be switching at too low a frequency due to a defect in the power transformer or associated oscillator-circuit capacitors or resistors.

Fuses

If the CB-set fuse blows (if there is a fuse) when the set is first turned on, look for a stuck vibrator or short circuit. Make sure the fuse is of adequate rating, but not too high, to avoid damaging the set.

If the fuse blows after the set has been turned on for a time, the fuse may be too low a value or there may be a short-circuit condition or excessive leakage that develops after the set has warmed up.

REPLACING COMPONENTS

It is always best to replace such components as power transformers, vibrators, and transistors with identical components. This is not always possible, particularly if the set is no longer on the market or if its manufacturer has gone out of business.

When transistors are used in the power supply, the power transformer is designed to work with the particular type of transistor used. The load characteristics also have an effect on transistor switching speed. If it is necessary to replace the power transformer, it may be wise to have it rewound if an exact replacement is not available.

Standard capacitors, resistors, and rectifiers of the same rating as the original, regardless of make, can normally be used to replace defective components.

Whenever a vibrator or switching transistor is replaced, it is a good idea to also replace the buffer capacitor, using one of the same capacitance and of the same or higher voltage rating.

PREVENTIVE MAINTENANCE

Vibrators have limited life and, as a preventive measure, should be replaced at regular intervals whose duration depends on the number of hours of use. When a set is turned on and off frequently, total vibrator life may be reduced, and replacement after fewer hours of use may be required.

Transistors, on the other hand, may have extremely long life and may not require replacement for several years. Transistor life depends on the design of the set, input-voltage variations, ambient temperatures, and the manner in which the set is installed. Adequate transmission of heat away from the transistors is required. A heat sink in the set does this partially, although the heat sink must have a flow of air across it. The set should be installed away from other sources of heat where there is adequate air circulation.

CHAPTER 7

Field Servicing

Troubles within a CB set are most easily corrected in the shop where adequate tools and test equipment are available. However, there are some troubles that are not caused by defects in the CB set and that must be corrected in the field.

Field servicing includes service calls at the customer's base stations, servicing of mobile units at locations away from the shop and servicing mobile units at the shop location.

Time and money can be saved by using mass-production techniques to check out a fleet of mobile units at one time. Taxi-fleet owners, for example, often arrange to have groups or all mobile units checked out at specific intervals. The cab drivers bring their cabs to the shop at a prearranged time, and technicians, each assigned to handle a specific chore (such as frequency check, etc.), tackle one cab after another. This technique, while more commonly used in servicing commercial fm mobile units, can be applied to check-out of CB-equipped fleets.

A mobile-CB check-out consists of the following steps:

1. Visual inspection of antenna, power wiring, mounting bracket, microphone, and microphone cord,
2. Measurement of transmitter frequencies (without removing the set from the vehicle),
3. Antenna-efficiency and rf power-output check (with thru-line-type rf power meter),
4. Receiver performance check (using a frequency meter placed near vehicle as signal source) with engine off and with engine running (to determine effects of voltage variations and presence of ignition interference),

5. Replacement of antenna, coaxial cable, etc., if required,
6. Replacement of CB set with a spare unit if set needs shop repair.

The same techniques are applicable whether checking out a single mobile installation or a fleet, at the shop parking area or at the customer's location.

ANTENNA TESTS

When a mobile CB set does not operate or when reception and transmission range is very short, and it has been determined that the set is receiving electric power, check the antenna system. This can be done quickly with a minimum of tools and test equipment.

All that is needed is a 12-volt lamp connected to the hot battery terminal and the antenna whip, as shown in Fig. 7-1. The lamp should light when the plug at the set end of the coaxial cable (pin and shell) is shorted with a screwdriver. If it does not light, the coaxial cable is open, the plug is not properly connected, or the cable shield is not grounded at the antenna base.

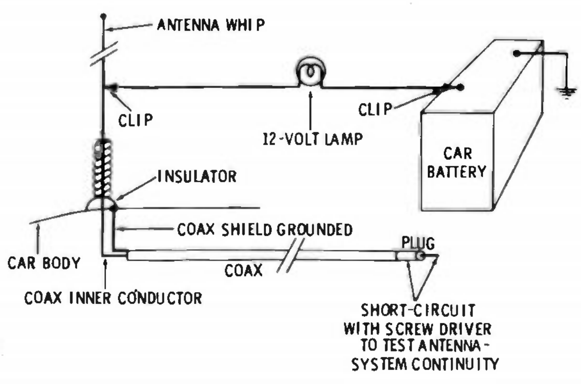


Fig. 7-1. Quick antenna check.

On the other hand, if the lamp lights without shorting the coaxial plug, the cable is shorted, the antenna whip is grounded, or the cable shield is touching the center conductor at the plug pin. This is not true when the antenna is of the shunt-fed base-loaded type shown in Fig. 7-2, in which case the lamp should glow whether the coaxial plug is shorted or not shorted.

It may be more convenient to listen to a buzzer or bell instead of trying to see if a lamp lights, particularly in daylight. An audible indicator can be used to test antenna circuits for continuity and shorts (Fig. 7-3). Disconnect the coaxial plug from the CB set and short the pin to the shell. The buzzer (or bell) should sound when the plug is shorted, and it should be silent when the plug is not shorted, except when the antenna is of a special type which normally has a dc shunt to ground.

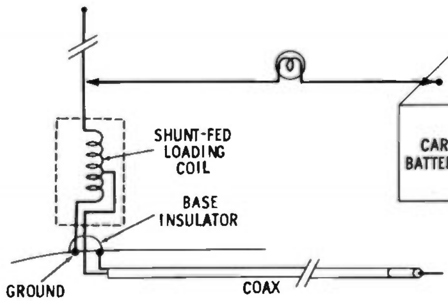


Fig. 7-2. Some types of antennas will indicate a short because of their design.

The above go-no-go tests will reveal dc shorts and open circuits. When one of these defects occurs, the antenna will be ineffective. If the set worked properly before, such a defect can be the cause of non-operation or drastic impairment of performance.

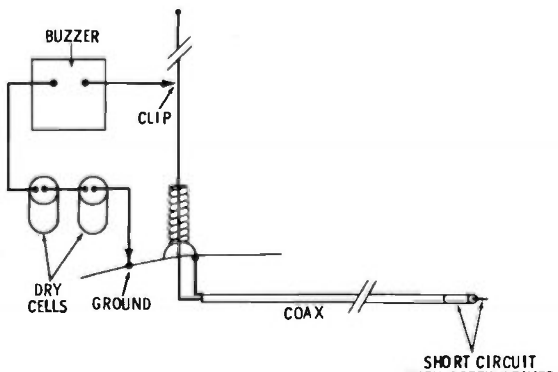


Fig. 7-3. Audible antenna check.

Field-Strength-Meter Test

On the other hand, if the CB set never did perform properly after installation in the vehicle, a short or open in the antenna system could be the cause. Inadequate range can also be caused by failure of the antenna to load properly. A quick way to determine whether the antenna is capable of radiating a signal at all is to place a field-strength meter a few feet from the antenna, as shown in Fig. 7-4. After listening to make sure the channel is not in use, turn the transmitter on (with antenna plug connected), announce the station call letters, and watch the needle of the field-strength meter. If it indicates zero, the antenna is not radiating.

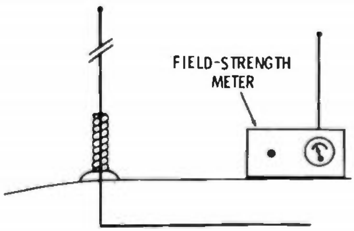


Fig. 7-4. Field-strength test.

Low-cost field-strength meters, which consist of a crystal-detector diode and a meter and are suitable for this purpose, are available from many sources (Lafayette, Heath, Radio Shack, etc.).

Antenna-Efficiency Test

A field-strength meter of this type is a handy go-no-go tester. To determine the efficiency of the antenna with greater precision, a through-line rf power meter can be used, connected in series with the antenna. There are many instruments of this type (available from Seco, Lafayette, Heath, Radio Shack, etc.). They are somtimes called antenna checkers, swr meters, reflected-power meters, bidirectional rf power meters, etc.

Such an instrument measures two conditions: *incidental,* or forward, power (power delivered by the transmitter) and *reflected,* or reverse, power (power reflected back and not absorbed by the antenna). The smaller the difference between these readings, the less efficient is the antenna. If the test reveals that a large percentage of the power is being reflected (not absorbed by the antenna), the trouble is usually due to improper tuning of the transmitter-output circuits, a defect in the antenna system, or improper antenna length or type. Fig. 7-5 shows an instrument of this type which can also be used as a field-strength meter.

Antenna-System Leakage

If the set performed properly in the past and performance deteriorated gradually, the trouble could be due to deterioration of the coaxial cable. Measure the leakage resistance of the antenna system with an ohmmeter (Fig. 7-6). The meter should indicate an open circuit, unless the antenna contains a shunt-fed loading coil. The resistance measured with a megohmmeter should be in the order of hundreds of megohms—beyond the range of typical ohmmeters. If leakage is detected, clean the insulator at the antenna base. If this does not eliminate evidence of leakage, disconnect the cable from the antenna. A leakage

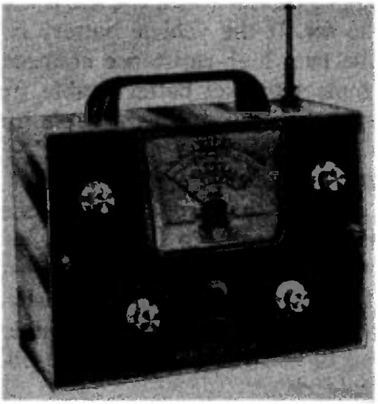


Fig. 7-5. Portable signal- and antenna-checking meter.

indication, with the antenna disconnected, makes it evident that the coaxial cable is defective and should be replaced.

An ohmmeter can also be used for checking antenna-circuit continuity and proper grounding, by connecting a clip lead (Fig. 7-6).

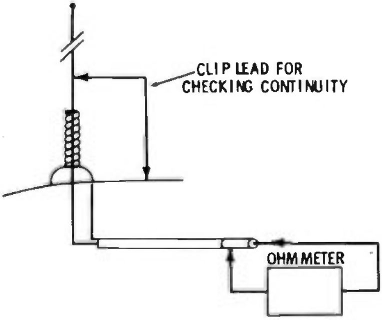


Fig. 7-6. Using ohmmeter to check antenna.

POWER-SOURCE TROUBLES

Lack of electric power is easy to detect. If the pilot lamp (if there is one) does not light or if the tubes do not light, power may not be reaching the CB set. The trouble could be due to an open connection inside the set or in the external wiring, or a blown fuse.

A quick way to find out is to disconnect the CB-set battery cable from the electrical system of the vehicle and measure the resistance across the CB-unit battery leads with the set ON-OFF switch turned on.

The resistance should be near zero (with solid-state units, you may have to try both ohmmeter polarities). If you get an open-circuit indication, check the cable, power plug, fuse, and power-circuit wiring of the set. Sometimes, electric power reaches the CB set, but the voltage at the set (with the set turned on) may be inadequate to operate the set. If the vehicle battery is fully charged, the trouble is usually due to a high-resistance connection. If this trouble is suspected, disconnect the set battery cable from the vehicle electrical system and temporarily connect the cable leads directly to the battery. Watch polarity—make sure the ground lead is not inadvertently connected to the hot battery terminal.

Should the results be the same with the CB-unit battery cable connected directly to the battery as when connected to the ammeter or other power take-off point, run the vehicle engine at fairly high speed. If the set operates satisfactorily under these conditions, the battery could be the cause of the trouble; or the vibrator may be "tired" and fail to start at normal engine-off voltage (in which case it should be replaced).

In some cases, the CB set may operate erratically or "spill over" into oscillation when the engine is running, if the voltage regulator is improperly adjusted. The voltage should not rise above 7.2 volts (6-volt battery) or 14.4 volts (12-volt battery). If it does, have the vehicle voltage regulator adjusted by a competent auto electrician.

MOBILE FREQUENCY CHECKS

CB transmitter frequencies can be checked without removing the CB set from the vehicle, if a portable, battery-operated frequency meter is available. The techniques are the same as described in Chapter 3. In extremely cold or hot weather the frequency measurements may be inaccurate if the frequency meter is not temperature con.-trolled. (The transmitter frequency may also vary under such climatic extremes.)

When making transmitter-frequency measurements with the CB set connected to a radiating antenna, listen to make sure the channel is clear before turning the transmitter on. Keep test transmissions short, and be sure to announce the station call letters. If the channel is too busy to make such measurements without causing interference to others, disconnect the antenna and connect the CB-set antenna terminal to a dummy load.

RECEIVER PERFORMANCE CHECK-OUT

When other stations can be heard, it is easy to determine if the receiver is sensitive by merely listening. In the absence of such signals, you can use a frequency meter if it contains a tone modulator as a signal source. Connect a short piece of wire or a plug-in whip antenna to the frequency meter, and place the instrument at a reasonable distance from the mobile unit. With the CB-set squelch control set to the fully *unsquelched* position, turn the frequency meter on and off and note if the signal quiets the receiver background noise.

Make these tests with the vehicle engine off and with the engine running, noting changes in performance. If the CB set has a noise limiter, turn the noise limiter on and off. When it is turned on, popping noises should be diminished in level and the test-signal audio level may also drop slightly.

EXCESSIVE NOISE

Rushing background noise indicates that the receiver is sensitive, but the signals are not strong enough. This condition is usually due to a defect in the antenna system. Sometimes it is due to the fact that the signals being heard are coming in from a great distance and are not strong enough to override the residual noise that is present in a normally operating receiver.

Popping noises heard when the vehicle engine is not running are usually picked up from other vehicles in the vicinity. Popping noises heard when the vehicle engine is running, and varying in rate as the engine speed is changed, are caused by the ignition system. A whining sound heard only when the engine is running is usually caused by the generator.

Many cars are factory equipped with ignition- and generator-noise suppressors. Instead of conventional spark-plug and distributor suppressors (series resistors), wire possessing several thouand ohms of resistance per foot is often used as a spark-plug lead and a distributor-to-ignition-coil lead. A capacitor is generally connected across the generator armature terminal and the generator frame. Another capacitor is connected across the body ground and the "hot" battery lead, generally at the ignition switch or ammeter.

This type of noise suppression is nearly always adequate for standard a-m broadcast reception, and sometimes for CB reception. In some cases, more adequate noise suppression is required for CB reception, since ignition noise is of greater intensity at 27 MHz than at lower frequencies.

Various types of noise-suppression kits, designed especially for CB radio, are available. Estes Engineering Co. and Hallett Manufacturing Company manufacture an ignition noise-suppression kit that includes shielded ignition cables, shields for the ignition coil and voltage regulator, and spark-plug shields. Sprague Products Company offers a noise-suppression kit that is designed specifically for CB use. Considerable work has been done in the field of radio-interference suppression by the Belden Manufacturing Co. This company has developed a special cable for use in auto ignition systems.

Also available is a booklet entitled *Giving Two-Way Radio Its Voice,* from the Automotive Technical Services Department, Champion Spark Plug Co., Toledo, Ohio.

The location of the antenna may contribute to noise pickup. Generally, the antenna should be as far from the engine as possible. Care should be exercised in routing the cable away from wiring that may act as a carrier for ignition noise.

Most late-model cars are equipped with rectifier-alternators in lieu of a dc generator. Since a commutator is not used, the whining generator noise is eliminated. However, there have been cases where the built-in silicon rectifiers combined with the alternator frame to produce radio signals at frequencies that cause interference.

BASE-STATION SERVICING

While a CB set is small enough to be brought into the shop for servicing, there may be troubles in the antenna system or power source, as well as troubles that exist because of the base-station environment, that require the attention of a technician at the base-station site.

Base-Station Antenna Troubles

The antenna at a base station may be inaccessible for inspection unless it is taken down. The system (antenna and transmission line) can be checked for short circuits and leakage by connecting an ohmmeter across the coaxial plug at the set end of the cable, as shown in Fig. 7-6 (should indicate open circuit). A cable continuity test cannot be made as shown in the diagram, unless the antenna is accessible, in which case the clip lead should be connected across the radiating element and the ground plane; a short-circuit condition should be indicated, but only when the test clip lead is in place. The above tests are not applicable when the antenna has a matching arrangement that provides a dc path across the antenna.

The most meaningful test of any type of CB antenna is made with a thru-line-type rf power meter (Fig. 7-5), connected in the same manner as at mobile stations.

Base-Station Receiver Check-Out

A quick way to determine if the antenna system is the cause of unsatisfactory reception is to try a plug-in antenna in place of the outside antenna. While such an antenna is seldom as satisfactory as an outside system, better performance with an indoor antenna usually indicates that the outdoor antenna system is at fault. This may not be the case when the outdoor coaxial cable is excessively long and therefore causing excessive signal attenuation.

Listening to other CB signals is the quickest way to determine if the receiver is operating in a reasonably satisfactory manner. When there are no signals from other stations, use a frequency meter as a signal source, as explained earlier.

Base-Station Power

The base-station electric power source is usually 60-Hz ac at approximately 120 volts. Most sets will operate satisfactorily when line voltage is as low as 110 volts. At lower input voltages, instability of the receiver local oscillator and transmitter oscillator may occur.

The availability of power can be easily determined by temporarily connecting a lamp to the ac outlet. If there is power at the outlet, there should be power at the CB set when its power cord is plugged into the outlet. If not, the set fuse may be blown or there may be an open connection. Look particularly for a broken connection at the molded ac plug at the end of the cord. If this is the case, or it is strongly suspected that it is, snip the cord an inch or so from the plug and install a new plug with screw terminals.

If the unit power plug fits loosely into the ac outlet or if it is necessary to bend the plug blades to make contact, try another ac outlet and advise the customer to have the power receptacle replaced. Poor connections here are a source of noise and erratic operation.

Grounding the Set

Under some conditions, the CB-set cabinet (if metal) is "hot" with respect to ground. The user may get a shock when touching the set while standing on a concrete or metal floor or when also touching a grounded object. The metal case of a microphone could, under some circumstances, be dangerous to touch.

This potential shock hazard can be avoided by grounding the chassis of the CB set. The reasons for the existence of this shock hazard are illustrated in Fig. 7-7. One side of the ac power line is normally grounded; the other side of the power line is therefore hot with respect to ground. The typical CB set contains a line filter consisting of two capacitors, C1 and C2, one connected to each side of the power line and chassis ground. They are, in effect, in series with each other, across the ac line. Their midpoint, which is connected to the chassis ground, is the midpoint of the voltage divider which they form. Hence, with the power switch (S) of the set turned on, the chassis is at a potential of approximately 60 volts above ground. With the power switch open and the set power plug connected to the line as shown in the diagram, the chassis is at a potential approximately 120 volts above ground. By reversing the plug in the ac outlet, the chassis will

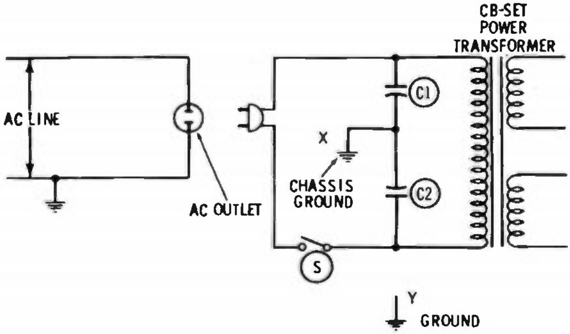


Fig. 7-7. CB-unit ac input circuit.

be at ground potential with the power switch turned off, and at half the line voltage above ground with the switch on.

When the set chassis is at a potential above ground, as described above, the current that can flow between the set chassis and ground is limited by the reactance of the capacitors (270,000 ohms for a 0.01-μF capacitor, 27,000 ohms for a 0.1-μF capacitor, at 60 Hz).

By grounding the CB-set chassis, the shock hazard is avoided, since point X (chassis) and point Y (external ground) in Fig. 7-7 are now at the same potential. The voltage across C1 is now the full ac line voltage and the voltage across C2 is zero. If the power plug is reversed in the ac outlet, the reverse is true.

The chassis of a CB set operated from house current is automatically grounded through the shield of the antenna transmission line (coaxial cable) if the antenna ground plane is grounded. If it is not, touching the antenna could cause a shock, unless the set chassis is grounded. The chassis ground connection sometimes reduces noise pickup and hum. Mainly, it adds safety. Capacitors C1 and C2 help reduce noise transmission to the set through the power transformer.

To ground a CB set, securely connect a wire to the chassis (under a screw head, etc., if a ground terminal is not provided). Connect the other end of the wire to a cold-water pipe, using a ground clamp. If the ground clamp makes an imperfect connection to the pipe, new troubles may be created. If a cold-water pipe is not available, a radiator is a fair substitute. Avoid gas pipes.

Noisy Reception

Ignition interference from cars in the vicinity is the prime source of CB interference. It is difficult to control when the noise transmitters are autos owned by others. Some relief is provided by the noise limiter. The real cure would be for all vehicles to be treated so that radiation of electrical interference is prevented (an unlikely situation).

At a base station, additional improvement in noise reduction can be made by moving the antenna farther away from the street and the areas traversed by motor vehicles. This is often impractical. Ignition noise is one of the annoyances CB users must learn to live with, at least until more effective noise-suppression means are developed.

Noise is also picked up from the house electrical wiring and electrical appliances. The causes and elimination of electrical interference is a subject in itself, well covered in other books on the subject.

Base-Station Transmitter Check-Out

Use a through-line rf power meter to check transmitter output and antenna efficiency as described earlier. Before turning the transmitter on, listen first to make sure the channel is clear. If the channel is busy, and you cannot afford to wait until it is clear, use a lamp-type dummy-antenna load to check the transmitter, and note its brilliance with the transmitter turned on. When you talk into the microphone, the lamp should flicker at a rate depending on the audio signal.

TWO-WAY COMMUNICATION CHECK-OUT

The proof of operational adequacy is the quality of the results achieved in actual use. If the customer has a mobile unit within range, try exchanging communications with it. If a customer's mobile unit is not available, you can talk to the CB set in your shop if it is within range and is equipped to operate on any of the customer's channels. Do not attempt to communicate with other CB stations operated by strangers, since this would be in violation of FCC rules. You can legally communicate from a customer's base station with your own shop base station only on those channels that are for interstation use. For this purpose, one of the 23-channel CB sets is a handy shop tool.

FIELD REPAIRS

Field repair of CB sets is usually limited to replacement of tubes and vibrators. Replacement of crystals and transistors and repairs that can affect transmitter performance (exclusive of tube replacement) should be made only in the shop where adequate transmitter-performance checks can be made.

SPARE SETS

A business user of CB buys his equipment to serve his needs, and once accustomed to having two-way radio, he is likely to be displeased if he has to stay off the air while his equipment is being repaired. A good way to please customers is to loan them a spare set while their equipment is being repaired.

CHAPTER 8

Shop Servicing

Adequate test equipment is required in the shop to make frequency measurements, measure performance, and diagnose troubles due to component failures. However, diagnosis of many troubles can be made with virtually no instruments, although there must be ac power for checking ac-operated sets and a battery or rectifier for checking dc-operated sets.

Many CB-set troubles can be diagnosed without having to dismantle the set. Only a few tools and a vom are required to quickly find the cause of most troubles.

CHECK ITS TEMPERATURE

The following check-out procedures can be made without taking apart the set, except to the extent required to get at the tubes in a tube-type transceiver.

With power connections made to a dc power supply or ac power line, depending on the set requirements, (make sure polarity is correct) and with the set power switch turned on, the tubes should light. Look at them in a subdued light since the glow in some tubes may be difficult to see due to the coating on the inside of the glass. If the tubes light and if there is no odor or smoke issuing from the set, leave it on for several minutes; then, touch the tubes with your fingers—they should feel warm to the touch. A cold or unlighted tube should be replaced with a new one of the same type. The set itself should feel warm to the touch after a few minutes of operation.

If all the tubes fail to light, recheck the power connections and try a new fuse (if the set has one). If the tubes light but only get slightly warm, chances are that the trouble is in the power supply. The vibrator in a vibrator-powered, dc-operated set should hum when power is applied to the set. Try a new vibrator if there is no hum or if the tubes do not heat up appreciably.

In the case of a solid-state transceiver, of course, no light will be noted unless the set has pilot lights or an illuminated channel-selector dial or an "S" meter.

When you have determined that the set is receiving power, connect a shop test antenna to the receiver-antenna connector receptacle.

NO SOUND

With the transmit-receive switch set to RECEIVE and with the volume and squelch controls set wide open, a rushing noise should normally be heard in the speaker. If no sound, not even a hum, is heard from a tube-type set, pull out the audio power-amplifier tube and listen for a click in the speaker. If you are unsure of which tube to pull out of its socket, pull them all out, reinserting each tube before pulling out another. To avoid a possible burn, wear a glove or use a cloth when pulling out the tubes; some of them may be hot.

Speaker Check

If no click is heard, the trouble may be either in the speaker circuit or in the audio power-amplifier stage. Connect an external speaker (a permanent-magnet type of any size) through a pair of wires to the terminals of the CB-set speaker (terminals 1 and 2, Fig. 8-1). If the set works now, replace the speaker.

When a spare speaker is not available, the set speaker can be checked (with the set turned off) by momentarily connecting the speaker terminals to a 1.5-volt flashlight cell. A click should be heard. If it is not heard, the speaker is defective.

Tube Substitution

On the other hand, if a click is heard when one or more tubes are being pulled out of their sockets, the speaker circuit is apparently operative. In this case, try a new tube in each socket, one at a time, putting each old tube back into its socket if a new one does not cure the trouble. When trying a new tube, be sure to allow enough time for it to warm up.

Crystal Substitution

A defective crystal can make the receiver silent. Try a new receiver crystal if one is available, even if it is not for the right channel. If a new crystal brings back the background noise, the old crystal should be replaced. It is also possible that the local oscillator could be so badly mistuned that it will not oscillate with the correct crystal inserted. In order to receive on the same channel, the crystal replacement must be ground to the same frequency as the original one.

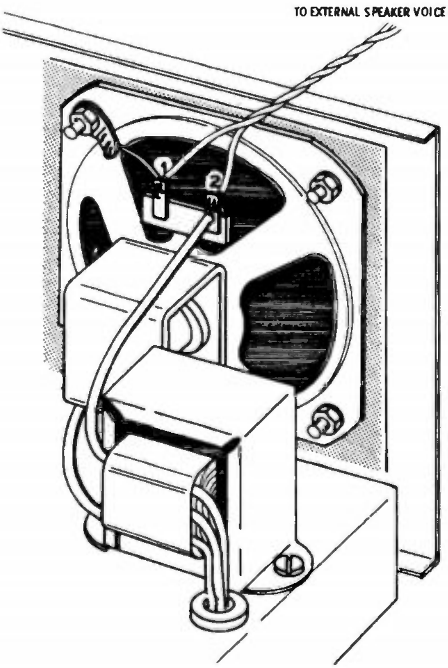


Fig. 8-1. Speaker connections.

When substitution of the receiver crystal, the tubes, or the vibrator does not restore proper operation, the trouble is probably such that the set must be dismantled and a more sophisticated diagnosis performed.

NOISE BUT NO RECEPTION

The existence of background rushing noise generally indicates that the receiver is functioning, although it may not be tuned to the right frequency. The trouble could be in the antenna switching circuit (often part of the transmit-receive relay). Try operating the push-to-talk switch several times; this might clean dirty contacts sufficiently to restore operation. If it does, examine the switch (or relay) contacts for dirt—cleaning them with contact-cleaning fluid might be the cure.

It is possible, although not probable, that the i-f transformer tuning has drifted sufficiently to make the receiver sensitive at an undesired frequency and inoperative at the desired frequency. In the case of a double-conversion superheterodyne receiver, this kind of trouble could be due to frequency drift of either the first or second local oscillator. Try new crystals in both oscillators. More elaborate measures that may be required are discussed later.

NOISY RECEPTION

Noisy reception could be a normal condition, particularly if the noise is caused by the ignition systems of nearby cars and trucks.

A reception accompanied by a steady rushing noise could also be normal if the incoming CB signals are weak. When a strong signal is received, the background noise should subside.

Detecting the causes of noisy reception—poor contact at the antenna switch (or relay), defective vibrator-hash-suppression filters, or misalignment of the i-f transformer—will require more elaborate means.

INSENSITIVITY

When a signal is not being intercepted, inadequate receiver sensitivity is often indicated by low background noise. Receiver insensitivity is most often caused by a defective tube. A quick way to find out if the tubes are the cause is to replace each tube, one at a time, waiting for the new tube to warm up and noting any improvement in performance.

Lack of sensitivity can also be due to poor contact in the antenna switching circuit or misalignment of tuned circuits. Misalignment can occur gradually due to aging of components. Aging causes physical changes in the components, resulting in changes in their electrical characteristics until the set no longer responds properly to the desired signals.

POOR SELECTIVITY

Interference from adjacent-channel stations is sometimes due to misalignment of the i-f transformers or to defective receiver crystals. Try a new receiver crystal. Often interference is a normal condition—some sets are not as selective as others and their tuned circuits are unable to reject unwanted strong adjacent-channel signals. Sometimes, of course, the offending station is not on its correct frequency.

ERRATIC PERFORMANCE

Sudden changes in the volume of an intercepted CB signal can be caused by poor connections, faulty tubes, and intermittent capacitors.

Tap the tubes, one at a time, while listening to a station, and note any change in performance or any introduction of noise. If any tube seems to be affected by tapping, try a new one. If performance is affected or noise is introduced when you strike the set gently, look for loose connections. Pay special attention to all of the connector plugs and receptacles.

NO TRANSMISSION

When the receiver operates but the set apparently will not transmit, place a field-strength meter near the test antenna and set the push-to-talk switch to transmit. If the meter indicates that power is being radiated, talk loudly into the microphone. The meter reading should vary as you talk. If not, try a new microphone. If the meter indicates that the transmitter is not operating, disconnect the antenna (with the transmitter off) and connect a No. 47 pilot-lamp dummy load to the set antenna connector. The lamp should glow when the transmitter is on.

INADEQUATE TRANSMITTING RANGE

If the customer complains that the transmitting range is shorter than normal, the trouble may be due to inadequate transmitter power output, insufficient modulation, or both. The transmitter power output and the modulation can be checked quickly and easily by connecting an ordinary No. 47 pilot lamp to the set antenna connector as was described earlier. When the transmitter is turned on, the lamp should glow brightly. When you talk loudly into the microphone, the lamp brilliance should increase in accordance with the modulation changes caused by your voice.

Inadequate transmitter power can be caused by an inactive crystal. Try a new transmitter crystal and note any difference in lamp brilliance. (If you leave the new crystal in place, measure the transmitter frequency.) A weak tube could be the cause—try new ones and note any improvement. Check the tuned circuits—the transmitter could require retuning.

A modulation level that is too low can be caused by a weak tube, an improperly tuned transmitter circuit, or a microphone that has an output that is too low. Holding the microphone too far away or talking too softly can also be the cause of inadequate modulation. Maximum range and voice volume at distant receivers are obtained when the modulation level is high. If in doubt about modulation level, try a new microphone of the same type or a different type of microphone of the same impedance and note if there is any increase in test-lamp brilliance.

PRECAUTIONS

When a blown fuse is replaced and the new fuse blows, do not attempt to operate the set until the cause of the overload is found and corrected. If you detect smoke or another odor when the set is turned on, shut off the set and look for a scorched part; continued operation may cause additional damage.

Make sure the battery polarity is correct (usually the red wire is positive and the black wire is negative) before turning on the set. Some sets operate with either polarity; others, particularly those employing transistors, may be damaged when input-power polarity is reversed.

Since electrical potentials as high as 300 volts can be encountered in tube-type sets when the set is turned on, exercise caution to avoid shocks from touching the circuit elements and the wiring. When working on a set operated from ac power on the bench, securely ground the chassis or stand on a dry rubber mat.

Do not bend, file, or sandpaper the switch or relay contacts. If they need cleaning, use a professional contact-burnishing tool or contact-cleaning fluid. To be safe, it may be wiser to replace a switch or relay that has faulty contacts than to attempt to repair it.

Never make prolonged transmitter tests with the set connected to a radiating antenna since you can cause harmful interference to others who may want to use the channel. Use a dummy antenna instead, such as a No. 47 lamp.

When a transmitter connected to an antenna is tested, keep the transmission short and announce the call letters assigned to the transmitter. (The call letters are posted on a license tag attached to the set.)

When a transmitter crystal is replaced, do not turn on the transmitter when it is connected to an antenna until the transmitter frequency has been measured and found to be within tolerance. The transmitter cannot lawfully be put on the air after the transmitter crystal has been replaced or after any work has been done that could affect the frequency until it has been checked out by, or checked out under the supervision of, a properly licensed radio operator.

Do not tamper with internal receiver or transmitter tuning adjustments unless you have adequate test equipment available to check the operation of the set.

SERVICING WITH INSTRUMENTS

When diagnosing CB-set troubles, the place to start is at the beginning—the power-input source. Use an ammeter (dc operation) or a wattmeter (ac operation) in the power-input circuit, as described in Chapter 6, to determine if the set is drawing rated, excessive, or too little current or power. If the power used is either excessive or insufficient, a short- or an open-circuit condition exists within the set, and the set must be disassembled so that other tests can be made to locate the defect.

Signal Tracing

If the set draws rated current or power, the receiver can be quickly checked by applying a signal to the antenna connector. A probe-type oscillator, which contains a multivibrator that produces essentially an all-frequency signal, is handy for this. Touch the probe of the tiny signal generator to the center contact of the antenna connector—a loud tone should be heard.

If no tone is heard (with the volume and squelch controls wide open), expose the bottom of the set chassis or pc board and touch the signal-generator probe to the output terminal of the af power amplifier. If no tone is heard in the speaker, measure the dc collector or plate voltage. If there is voltage, the trouble could be an open speaker, open output-transformer secondary (not likely), or an open connection in the speaker-control portion of the transmit-receive switching circuit.

If the tone is heard, touch the probe to the input terminal of the af power amplifier. The tone heard in the speaker should be much louder. If no tone is heard, the transistor or tube could be defective.

If the tone is heard, move the signal-generator probe to the input of the first audio amplifier, then to the detector and successively to the i-f amplifiers, mixer, and rf amplifier. The tone should be heard in each instance.

However, if no tone is heard when the signal is injected at the input of the first af amplifier, the trouble is either in the first audio-amplifier stage or the coupling capacitor. No tone at the detector indicates trouble in the noise-limiter or squelch circuit. Absence of tone when the signal is injected at the mixer indicates trouble between the test point and the preceding test points, somewhere in the i-f amplifier circuits. If no tone is heard or if the tone is weak when the signal is injected at the receiver input, the trouble could be in the rf amplifier stage or in the local oscillator.

Using a Tunable Signal Generator

The preceding procedure is a simple way to localize the cause of inoperation of a receiver. If a conventional tunable rf signal generator is used instead of a multivibrator-type signal injector, it is necessary to tune the signal generator to the appropriate frequency.

If you suspect that a local oscillator is not functioning, check it by injecting an unmodulated signal at the input of the mixer through a very small capacitor (2 pF or so) and by slowly tuning the signal generator through the appropriate frequency range. With an antenna connected to the CB set, you should be able to tune in CB stations since the signal generator functions as a tunable local oscillator; its output beats with the station signals to produce the i-f.

Voltage Test

Receiver troubles can also be diagnosed by measuring dc voltages at the various tube sockets and transistor leads. The correct voltages are often noted on receiver schematics or in voltage-measurement tables published in instruction books. However, there are instances when all dc voltages appear to be normal, yet the set will not operate because a signal path somewhere in the set is open. In such cases, it is necessary to resort to signal tracing or other methods.

There is one dc voltage, however, that depends on the rf signal; that is the agc voltage. Agc voltage should be measured with a dc vtvm instead of a vom to avoid loading down the agc bus by the lower meter resistance of the vom.

When a signal is being received or is injected at the antenna terminal, the agc voltage should rise. If it does not rise or there is no agc voltage, the signal is not getting through as far as the detector.

Replacing Receiver Components

Capacitors in the rf amplifier, mixer, and local-oscillator stages are apt to be critical, and each should always be replaced by one of identical type, value, and rating.

All coils should be replaced by identical types. However, replacement of i-f transformers with standard general-replacement types may not be harmful. Sometimes the selectivity characteristics of the receiver might be affected or instability may result due to higher-than-normal gain. Be careful to dress leads as they were originally to avoid creation of unwanted feedback paths.

TRANSMITTER DIAGNOSIS

Some transmitters are equipped with an rf power meter to facilitate tuning without requiring external test equipment. Test points are provided in some transmitters to permit easy connection of a test meter. Others have no designated test points. Nearly all can be tuned using only an rf power meter or a lamp-type dummy load as a tune-up indicator.

When a transmitter is not equipped with an rf power-level meter, an external rf power meter with a built-in dummy antenna load or a through-line rf power meter terminated in a 50-ohm dummy load (instead of an antenna) is required for bench checking and tune-up of transmitters.

Ample drive but insufficient power output indicates that there is trouble in the rf amplifier stage. This may be due to a defective tube or transistor, mistuning, or a change in the value of a resistor.

Neutralization

Neutralization is used in some CB transmitters to prevent self-oscillation by the rf power amplifier. The presence of an output signal when the transmitter crystal is removed indicates that the rf power amplifier is oscillating. Neutralizing adjustments should be made in strict accordance with the set instruction book.

Low Modulation

The rf power meter indicates rf output when the transmitter is either modulated or unmodulated. With modulation, the power-output indication should rise. The effective talk-power and range of the transmitter are seriously reduced when the modulation level is inadequate. Methods for measuring modulation level are described in Chapter 4.

An inadequate modulation level can be caused by (1) improper use of the microphone; (2) insensitive or improperly matched microphone; (3) improper voltages; (4) defective tube in modulator stage or preceding af amplifier stages; or (5) defective component in the modulator system.

An amplitude modulator is simply an audio amplifier that applies a varying audio voltage in series with the dc voltage applied to the rf power amplifier. Distorted audio is caused by the same defects that cause distortion in conventional audio amplifiers.

TROUBLESHOOTING CHART

Some manufacturers furnish excellent instruction books containing troubleshooting charts, voltage and resistance charts, and other information that makes servicing easier. Chart 8-1 on troubleshooting procedures is generally applicable to all CB sets.

Chart 8-1. Troubleshooting Procedures

Entire Transceiver and Power Supply

Trouble	Probable Cause	Remedy
Pilot does not light. Rest of set is dead.	No line-voltage input. A. Blown fuse. B. Defective on-off switch. No B+ voltage A. Defective line filter capacitors. B. Defective vibrator or power-supply transistor. C. Defective filter capacitors. D. Defective power transformer. E. Defective rectifier. F. Open filter resistor or choke.	Check voltages. Check for shorts and measure resistance as per resistance chart or schematic. Replace defective parts. Replace buffer also if vibrator is replaced.

Chart 8-1. Troubleshooting Procedures—cont

Trouble	Probable Cause	Remedy
Filaments do not light.	No ac or dc power input, blown fuses, or defective transformer. Defective line filters.	Check voltages and resistances. Replace defective parts.
No sound from speaker. Cannot transmit. Pilot indicator O.K. Filaments O.K.	No plate or collector voltage. Defect in power-supply rectifier circuit. Short in power branch circuitry.	Check voltages and resistances. Replace parts found defective.
No B+ or V_{cc}	Bad rectifier or filters, open resistor, or shorted buffer capacitor. (Open rectifier diodes cause low B+. Shorted rectifier diodes cause the power transformer to burn.)	Check voltages and resistances. Check rest of circuit for shorts. Replace defective parts.
No sound in receive position. Power supply operative. Modulator inoperative.	Defective speaker or output transformer. Defective part in modulator. Defective microphone "press-to-talk" switch.	Check voltages and resistances. Replace or repair defective components.
Intermittent.	Tubes, shorts, cracked pc board, or broken wires due to vibration.	Check tubes by gently tapping. Make physical check for loose or broken wires or cracked pc board. Make resistance check.
Excessive hum.	Defective filters in power supply.	Check filters by substitution. Replace defective parts.
Dial calibration is off (tunable receiver).	Dial may have been forced or turned. Rf tracking off. (Must be reset if any frequency-sensitive component has been replaced.)	Reset dial. Realign receiver.
Meter needle sticks.	Meter face acquired static charge.	Discharge by wiping face with antistatic cloth.
Meter stays fully deflected or at zero.	Defective related component. Zero-adjust potentiometer shorted or open.	Check components for defects. Replace if defective.

MODULATOR

Trouble	Probable Cause	Remedy
Excessive hum pickup.	Wires from on-off switch to power supply pass too close to modulator. Defective microphone cord.	Dress wires under power supply close to chassis. Replace or repair cord.
Loud crackling noise from speaker.	Defective speaker voice coil is shorting to ground. Defective transistor.	Replace speaker. Replace transistor.
Low or distorted audio. Low or distorted modulation.	Defective part in modulator. Defective microphone, defective modulation transformer, or defective part in modulator.	Check tubes first, then make voltage and resistance checks to determine bad part. Replace defective components.

Chart 8-1. Troubleshooting Procedures—cont

RECEIVER		
Trouble	**Probable Cause**	**Remedy**
Fixed tune not working or erratic.	Defective wire from switch to crystals and/or trimmers. Defective fixed-tune trimmers (if used).	Check wires and trimmers for shorts. Replace if defective.
Cannot tune .high channels with fixed-tune trimmers.	Excessive trimmer capacitance.	Add capacitor in series with trimmer and switch.
Burned resistor.	Defective capacitor, shorted or gassy tube, or shorted transistor.	Check tubes, transistors, and capacitors. Replace bad parts.
Noise limiter ineffective or inoperative.	Defective diode or component in noise-limiter circuit.	Check diode and components for voltage and resistance as per charts or schematic.
Receiver drift.	Defective crystal.	Try new crystal.
Rf interference.	Tube shields missing.	Make certain tube shields are in place.
Adjacent-channel interference.	Tuning of i-f transformers too broad.	Realign receiver or consult manufacturer.
Interference from out-of-band station.	Inadequate rejection of strong out-of-band signals.	Construct and install wave trap at antenna input.
Short range.	If set checks O.K., customer's antenna may be defective.	Check antenna, cable, and connector.
TRANSMITTER		
Cannot transmit. Microphone and cord O.K.	Defective transmitter.	Check tubes, transistors, voltages, resistance, and components for defect.
Low rf output.	Defective component in transmitter. Transmitter out of alignment.	Check tubes first, then check alignment. Check for defective components. Make voltage and resistance checks. Replace defective parts.
Off frequency.	Defective transmit crystal. Defective oscillator tube. Crystal trimmer (if there is one) defective or out of alignment.	Check oscillator tube and crystal. If bad, replace. Replace or retune trimmer. Remeasure frequency.
Slow return of receiver after transmission.	Defective rf amplifier tube in receiver. Defective detector/avc tube. Defective component in squelch circuit.	Check tubes. Check voltage and resistance. Replace bad parts.
Cannot transmit. Receiver and transmitter operative.	Defective microphone cord, switch, microphone or connector.	Check for defect. Repair or replace bad part.
Feedback (whistle-type noise) while transmitting.	Modulation-transformer leads reversed during repair. Open capacitor across modulator-transformer primary.	Check wiring. Replace capacitor.
Microphonics in receiver or transmitter.	Defective tubes.	Check all tubes by gently tapping to find microphonic tube.

SHOP CHECK-OUT

Repair of CB sets is only part of the service technician's job. After repairs have been made to restore operation, a CB set should be completely checked out to make sure it delivers all of its original performance and to make sure it complies with FCC requirements. The following check-out and service procedures are basic good practice.

Cleanliness

Dust and dirt inhibit cooling and cause leakage paths. Clean off accumulated foreign matter with a vacuum cleaner (not forced air) and a dry paint brush. When necessary, clean parts with a safe solvent. Do not use carbon tetrachloride; it dissolves some kinds of insulating materials, corrodes some metals, and is poisonous to breathe. Clean the relay and switch contacts with contact-cleaning fluid—but never file them.

Tubes

Test all tubes with an accurate tube tester for shorts, merit (dynamic mutual conductance, transconductance, or emission), grid emission, and interelectrode leakage. Replace all tubes that have any defects. Bear in mind that all tubes which pass muster on a typical tube tester will not necessarily perform adequately in your set. If performance is not as rated, use the tube-substitution method in addition to checking the tubes with a tube tester.

Transistors

It is easy to check a transistor stage without removing the transistor. Almost every transistor stage has a resistor in series with the emitter, as shown in Fig. 8-2. To check the transistor functioning, simply measure the dc voltage across this resistor. While doing so, use a clip lead to momentarily short the emitter to the base. The voltage reading should drop since the forward bias on the base is thus removed, causing the emitter current to drop. If the voltage does not change, the transistor undoubtedly is not functioning.

In a circuit containing a pnp transistor, the collector should always be negative with respect to the emitter and the base should be *slightly* negative with respect to the emitter. Just the opposite is true with regard to the polarity in a circuit employing an npn transistor.

If a transistor is open (or if the base bias is zero or of reverse polarity), the collector-to-emitter voltage will be equal (or almost equal) to the supply voltage and there will be no voltage across the emitter resistor. If a transistor is shorted, there will usually be no dc voltage between the emitter and collector and the voltage across the emitter will be equal (or almost equal) to the supply voltage.

Since most transistors in CB transceivers are soldered in place (not plugged in), they can be checked only as described above or with an in-circuit transistor checker. To use this kind of instrument, turn the transceiver off and then connect the checker leads to the transistor leads.

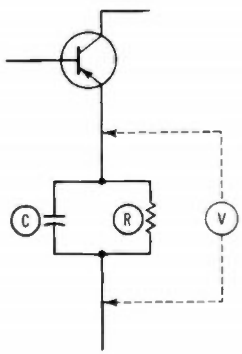


Fig. 8-2. Transistor check point.

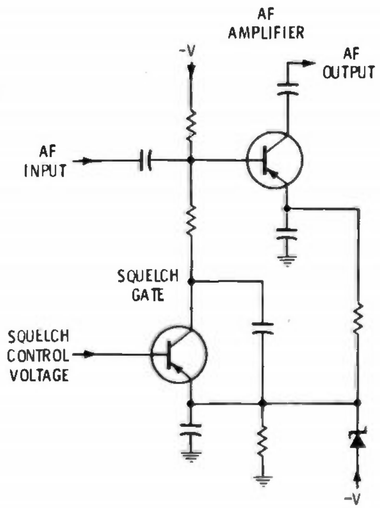


Fig. 8-3. Squelch-controlled af amplifier circuit.

Ordinarily in rf, mixer, and i-f stages, the transistors are forward biased. This causes collector current to flow at all times. (Tubes, on the other hand, are reverse biased to limit plate current.) An af amplifier stage controlled by a squelch circuit usually has no forward bias on the base or is reverse-biased so that it does not conduct until unsquelched. In Fig. 8-3, the amplifier transistor conducts only when the intercepted signal is strong enough to overcome the squelch. A Class-B af amplifier stage (Fig. 8-4) is only slightly forward biased. Collector current is low when no signal is present; it rises as the signal level increases. The voltage across the emitter resistor (R) should increase with signal level.

The collector current of an rf or i-f amplifier stage with gain controlled by agc is maximum when no signal is being received and is reduced when a signal is present. In Fig. 8-5, detector diode X develops at its output a dc voltage level that rises with the strength of an intercepted signal. This voltage reduces the forward bias of rf and i-f amplifier stages with agc.

Changes in the values of base-bias resistors can cause nonlinear operation or nonfunctioning of a transistor amplifier. In Fig. 8-6, resistors R1 and R2 form a voltage divider and, when their values are correct, provide the correct base bias voltage at their junction. The voltage at the junction of the two resistors is not exactly proportional to their resistance values since the base draws current. Therefore, the

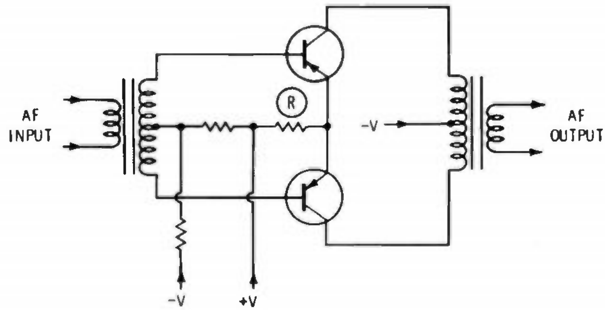


Fig. 8-4. Class-B push-pull af amplifier.

current through R2 is equal to the sum of the base current plus the current through R1.

Base bias can also be incorrect if the coupling capacitor feeding the transistor base is leaky or shorted. In Fig. 8-7, for example, the collector of the previous stage (pnp transistor) is normally more negative than the base of the transistor it drives. If the coupling capacitor (C) is open, the bias will not be affected, but little or no signal will

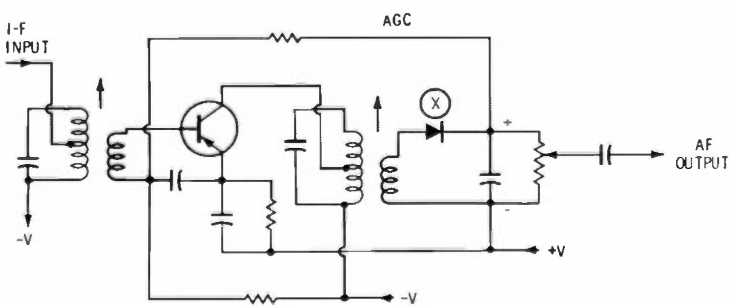


Fig. 8-5. I-f amplifier with agc.

pass through. If the capacitor is leaky or shorted, the forward bias on the driven transistor may be excessive.

Often these coupling capacitors, especially in af circuits, are electrolytic types which are polarity sensitive. When replacing one, make sure the capacitor is connected so that it is subjected to voltage of the proper polarity.

A shorted or leaky bypass capacitor across an emitter resistor (C in Fig. 8-2) will cause the forward bias to be excessive. If the capacitor is open, the gain will be reduced because of degenerative feedback.

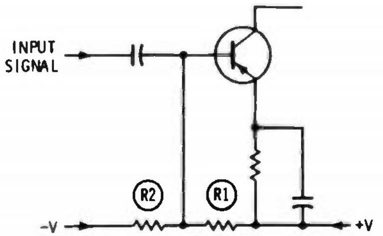


Fig. 8-6. Typical biasing arrangement for transistor.

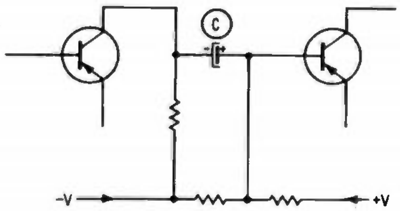


Fig. 8-7. Capacitive coupling.

Integrated Circuits

Integrated circuits (ICs) are used in some CB transceivers. An IC may contain several transistors (some also contain diodes) in a package often as small as a single transistor. An IC may be used as an rf, i-f, or af amplifier, or it may perform the functions of an af amplifier and a squelch circuit plus an agc circuit.

It seldom, if ever, is practical to repair an IC. If defective, the entire IC should be replaced. Care must be exercised (as in the case of transistors) when removing and installing an IC to prevent heat damage when soldering its leads.

Cables and Connectors

Inspect all cables for frayed insulation and loose strands of wire, as well as soldered connections at plugs. Replace worn cables and plugs. If the antenna connector does not match the plug on the customer's antenna coaxial cable, either install the proper type of plug or use an adapter—makeshift coaxial connections lead to rf power losses.

Microphones

The microphone is the device which is fed the intended intelligence. If the customer has an inadequate microphone, sell him a better one but make sure its electrical characteristics match the set. Pay particular attention to push-to-talk switch contacts and microphone-cord shielding. Replace worn microphone cords; they are not expensive, and a new one can save a later (free) service call.

Power Supply

Replace vibrators or switching transistors whenever there is any doubt as to their continued reliability. Replace the buffer capacitor with one of the same value and same or higher voltage rating when replacing a vibrator. Electrolytic filter capacitors dry out; replace them if they have been in service for two years or more.

Receiver Performance

Always check out a receiver for sensitivity and make sure that the receiver is as sensitive as its rating (usually less than 1 microvolt for 10-dB signal-to-noise ratio). Also, determine that the squelch opens with less than a microvolt input when set to best squelch sensitivity. Make sure that the squelch can be set so it will not open on normal noise.

While there is little you can do about improving selectivity, you should measure it and realign the receiver if its selectivity is down.

While measuring sensitivity, increase the modulated rf signal input and make sure the full-rated audio output is obtained without excessive distortion. Ac voltage at speaker terminals should be equal to $\sqrt{WR}$ when W is the rated audio output in watts and R is the speaker impedance in ohms. To determine that the avc is working, listen for an audio output-level change as the input signal is increased.

Listen for a decrease in ignition noise when the noise limiter is cut in. It should reduce noise but should not cause an excessive drop in speech level and *serious* introduction of distortion.

Using an accurate frequency meter, determine that all receiving channels are "on the nose." Let the set operate for a while and recheck it to make sure it has not drifted.

Transmitter Performance

The customer looks to you to keep him out of trouble with the FCC in regard to transmitter performance. Measure the transmitter frequencies, and replace the offending crystals if any channel is close to being off frequency by 0.005% (0.0025% is a better standard to use). Recheck for drift after letting the set operate for a while.

Measure the power output with an rf power meter. If the output is less than 3 watts, your customer may be dissatisfied. If it is over 4 watts (or 12-watts pep on ssb), the FCC will not be happy. Also measure the power input to the final rf power-amplifier stage if it can be done without undue inconvenience. Do this with the transmitter on and connected to an rf power meter and/or dummy load.

To measure the approximate power input to a solid-state transmitter, measure the collector current with a dc milliammeter and multiply the meter reading by the collector-to-emitter voltage. This may not be convenient to do. It is easiest to measure the rf output with an rf wattmeter connected to the transceiver antenna terminal.

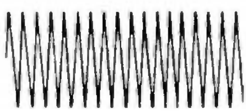
Measure the modulation with an oscilloscope as described in Chapter 2. Make sure the modulation is linear (equal up and down) and is above 70%, but never over 100%.

Fig. 8-8 shows the patterns of various types of signals that can be seen on the screen of a scope. The various patterns represent the following kinds of signals:

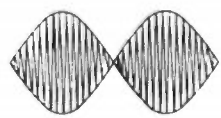
A. An unmodulated carrier of an a-m transmitter.
B. A 100% modulated a-m signal.
C. A 73% modulated a-m signal.
D. An ssb signal modulated by a single tone.
E. An ssb signal modulated by two tones of equal amplitude.
F. An ssb signal modulated by three tones of equal amplitude.
G. An ssb signal modulated by a voice signal.

If the set has a tvi filter in the antenna circuit, turn on a tv set tuned to tv channel 2 and operate the transmitter. Adjust the tvi filter for minimum effect on tv reception, or use a grid-dip meter and tune the filter to approximately 54 MHz.

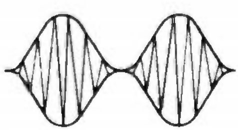
If there is no tvi filter and serious tv interference occurs, sell the customer a low-pass filter designed to cut off above 30 to 40 MHz and for use in a 50-ohm unbalanced line. Connect it between the set antenna terminal and the antenna with a piece of cable fitted with ap-



(A) Carrier.

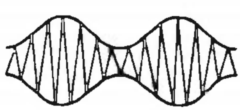


(B) Ssb, 2 tone.



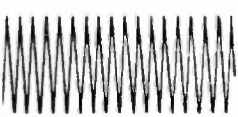
(C) A-m, 100% modulation.

(D) Ssb, 3 tone.



(E) A-m, 73% modulation.

(F) Ssb, Voice.



(G) Ssb, 1 tone.

Courtesy Bird Electronics Corp.

Fig. 8-8. Scope patterns of various types of signals.

propriate plugs. Fasten the filter to the CB-set chassis or case, making sure the filter case is securely grounded to the set.

Record Your Work

Keep a log and make a reference list for the following facts about every set you service:

1. Make, model, and serial number of set.
2. Name, address, and station call letters of the set owner.
3. Date on which set was serviced.
4. Signature of person servicing set.
5. Grade of operator license and license expiration date held by person servicing set or responsible for work done.
6. Repairs made; list of tubes and parts replaced.
7. Actual measured transmitter frequencies.
8. Rf power output at all channels for which set is equipped.
9. Receiver sensitivity at all channels for which set is equipped.
10. Power input voltage applied when measurements were made.

If you wish to be a good salesman, attach a sticker to the set, noting the actual measured transmitter frequencies, the date they were measured, and the name of your company. This will help protect your customer if he gets an FCC citation for off-frequency operation and will remind your customer to call you when service is again required.

MODIFICATIONS

Recently enacted changes in FCC rules prohibit modifying type-accepted CB transceivers or replacing components with any but those recommended by the transceiver manufacturer, without written FCC permission. If modifications are made, either written FCC permission must be obtained or a new application for type acceptance must be filed. (See Parts 2 and 95, FCC Rules and Regulations for type-acceptance procedures and technical standards.)

Keeping up-to-date with FCC Rules can be difficult. It may take several months before rules amendment sheets are issued by the Government Printing Office. All CB service technicians should possess a copy of Volume VI, FCC Rules and Regulations, which is available for $5.35 from the Superintendent of Documents, Government Printing Office, Washington, D.C. 20402. However, one cannot be assured of immediate delivery of a copy of the rules. To keep up-to-date, one can subscribe to the *Federal Register* (also published by the GPO) which lists rules changes, new rules, and proposed rules a few days after FCC action has been taken.

In Canada, the rules governing the General Radio Service (equivalent of the U.S. Citizens Radio Service) can be obtained from the Queen's Printer or the Department of Communications in Ottawa.

CHAPTER 9

Business Aspects of CB Servicing

With new station-license applications flowing into the FCC at a rate of around 200,000 per month, the CB servicing business has interesting potential. It is estimated that some 400,000 CB transceivers are being sold monthly. While many buy only one set initially, some buy several as they become aware of the value of CB communication.

Most CB sets are sold by radio-part jobbers, mail-order houses, and auto-accessory stores, which may or may not have service facilities. Citizens Radio speciality stores, on the other hand, generally maintain service departments. Many users go to professional two-way radio service shops when they experience trouble—others attempt to repair their own sets. The rapid growth of the CB radio market is causing many tv-service-shop operators to expand into CB servicing.

CB SERVICE SHOP

To get into the CB service business, adequate test equipment is required. While an unlicensed technician can service CB sets under certain conditions, a CB shop should employ at least one person holding a First-Class or Second-Class Radiotelephone Operator license. The licensed man is responsible for the work performed by unlicensed persons who work under his supervision. However, the technical work should not be difficult for a tv serviceman, since servicing tv sets requires more knowledge and skill than servicing transmitters. Therefore, to secure a part of the lucrative CB business, every tv serviceman should bend his efforts toward securing an FCC license.

The CB shop can participate in the multimillion-dollar CB business by offering any or all of the following services:

1. Repair of CB sets for local radio-parts jobbers and local CB users.
2. Installation of CB sets for local radio-parts jobbers as well as installation of those purchased from mail-order houses.
3. Installation and sale of noise-suppression kits.
4. Installation and sale of improved antennas, lower-loss coaxial cable, etc.
5. Direct installation and sale of CB sets to users.
6. Frequency-measuring service for local dealers and users.

The first step in entering the CB service business is to obtain a radio operator's license. The next step is to become better informed about CB equipment by reading books and magazines. Instruction books on actual sets can often be obtained free of charge by writing directly to CB-equipment manufacturers, whose success depends on the availability of service on a local level.

Shop Equipment

Adequate test equipment is essential. A listing of the minimum test equipment required is given in Chapter 2. A minimum investment of approximately $1000 in test equipment is required. Two or three times that amount is required if laboratory-type equipment is selected.

Inventory

To profit from sales of antennas, a small inventory of various types of antennas, coaxial cables and related hardware should be maintained. It will also be necessary to stock tubes, vibrators, and standard parts. Those who are in the legitimate CB service business can purchase these parts from local radio-parts jobbers at wholesale prices. These parts are also available at advertised net prices from mail-order houses.

It is not feasible to stock crystals unless many of the same makes and models are to be serviced. Crystals must be ground specifically for use in a particular set and are not interchangeable among various makes and models of CB sets. While a crystal ground for set A will work in set B, chances are that set B will not operate at the required frequency. Exact replacement parts and crystals must generally be purchased directly from CB-equipment manufacturers, their distributors, or through their sales representatives serving your area.

To participate in sales of CB equipment, contact the manufacturers of your choice and advise them of your interest. Some brands may not be available to you due to prior arrangements for distribution in your area.

When you buy CB equipment for resale, your cost often depends on the number of sets you want to buy. For example, one manufacturer allows a discount of 30% from suggested retail price when small quantities are ordered and 40% when 50 or more sets are purchased at a time. You, however, determine the price at which you sell the equipment. The advertised price is a "suggested" retail price and is not a price at which you are required to sell.

When engaging in the service business, you are primarily selling services, and sales of equipment, parts, and accessories are secondary. Neverless, hardware sales can add significantly to your income.

SERVICE CHARGES

The rate you must charge for services depends on your costs and overhead. While a rate of $10 per hour is adequate in some areas, $18 per hour may not be enough in others. An equipment manufacturer must charge from $100 to $500 per day for the services of a field engineer or technician in order to defray out-of-pocket costs and overhead.

The following service charges are typical (not including material):

Install base station and antenna	$100.00
Install mobile unit and antenna on car	$ 25.00
Replace existing base-station antenna and coax	$ 50.00
Service call, base station, minimum charge	$ 15.00
Service call, mobile unit, minimum charge	
—car brought to shop	$ 10.00
—call at customer location	$ 15.00
Install noise-suppression kit in car	$ 25.00
Install CB set and antenna on boat	$ 75.00
Frequency measurement—first channel	
—set brought to shop	$ 10.00
—at customer location	$ 15.00
Frequency measurement— additional channels, each	$ 2.50
Shop labor	
—minimum charge	$ 10.00
—hourly rate	$ 18.00
Complete check-out of set—at shop	$ 25.00
Change frequency or replace crystals	
first channel	$ 12.50
—additional channels, each	$ 5.00

Commercial customers generally expect to be extended credit. If you do not know the customer's paying habits, it is a good idea to get bank references or subscribe to Dun & Bradstreet credit-information service. Many commercial customers will be interested in having their equipment serviced on a contract basis. Typically, the charge is $25 per month for maintaining a base station and $15 per mobile unit, material included. For this, the customer is entitled to one preventive-maintenance call per month and unlimited emergency service during normal business hours.

Some manufacturers will arrange with local independent service shops to handle any maintenance problems that may occur during the warranty period.

PROMOTING CB SERVICE BUSINESS

You can succeed in the CB service business only if you let your prospective customers know that your services are available. Your markets include local CB-set users, local distributors of CB equipment, and manufacturers and distributors who sell equipment in your area by mail.

To reach local CB-set users, you can advertise your services in local newspapers and on local radio stations, as well as at your place of business and on your service vehicles. You might also advise the FCC office nearest you that your services are available to those who inquire about local CB-set service. A personal call on all radio-parts jobbers in your area may produce subcontract service work or referrals of service calls to you.

By all means, write to several CB-equipment manufacturers and tell them about your availability and qualifications. Many mail-order houses might also be happy to know of the availability of your services in case of need.

When doing a large volume of business, it may pay to have spare sets available for use as *loaners*. To meet the requirements of all customers, the spare sets should be of the type that are operable on all 23 channels. Thus it will not be necessary to install crystals for a customer's frequency since these sets can be set to any channel without modification.

You can also rent CB sets. However, a renter must have his own station license—he may not legally use a rented set without a license, or under your license. Typical rental charges for a set selling for $190 are as follows:

One day	$15
One week	$35
One month	$75
One year	$20 per month
Five years	$10 per month

For these rental fees, you should handle maintenance without additional charge if the customer brings the set to your shop for service or if you furnish loaners while repairs are being made. Since costs vary, you should consult your accountant or bank when establishing rental rates. When you lease equipment on an annual or longer-term basis, your bank may be willing to purchase your lease contract and free your money for other purposes.

Index

CB RADIO servicing guide

THIRD EDITION

by LEO G. SANDS

With the ever-increasing number of CB sets in use, the problem of maintaining them in good working order has increased. This book has been designed to serve as a helpful guide to quicker, easier CB servicing, both for the service technician and the technically inclined CB user.

Troubleshooting procedures, aimed at fast repair of both receivers and transmitters, make up a large part of this book. Receiver circuits are analyzed; methods are included for receiver alignment, measurement of receiver sensitivity, and determination of the causes of low sensitivity, poor selectivity, distortion, and intermittent operaton. Step-by-step analysis of transmitter circuits includes sections about crystal oscillators, modulators, power amplifiers, and antenna-tuning and antenna-coupling networks. The many illustrations range from CB-radio schematics to test-equipment diagrams and charts showing how much range can be expected from CB radio.

Information regarding CB-radio laws and regulations is included to point out equipment-performance requirements and which kinds of maintenance can be performed only by a licensed operator. For the professional service technician there are chapters on field and shop maintenance and the business aspects of CB-radio servicing.

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Leo G. Sands is president of Sands Technology Corp., an engineering and telecommunications systems consulting firm based in New York City. He has held executive and engineering posts with RCA, Bendix, Philco, and Curtiss-Wright. His early experience was obtained selling and designing sound systems for Remler Company, Ltd. and de Forest Phonofilms.

Mr. Sands is a senior member of the Institute of Electrical and Electronics Engineers and for two years was chairman of the New York Metropolitan Chapter IEEE Vehicular Technology Group. He is a Fellow and a member of the board of directors of The Radio Club of America and has served as executive secretary of the club.

Mr. Sands has written over 1200 magazine articles and numerous books, including *Sound Systems Installers Handbook*, *Mobile Radio Systems Planning*, and books using the question and answer format on the following subjects: *Transistor Circuits; CB Antennas; Auto Tape Units; AM, FM, & SSB; Color TV; Fixed Radio Communications;* and *Electricity*, published by Howard W. Sams & Company, Inc.

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