MOBILE POLICE COMMUNICATIONS

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STUDY SCHEDULE No. 50

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

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MOBILE POLICE COMMUNICATIONS

Police Radio Systems

POLICE radio systems have been used extensively for many years. The radiotelephone is today one of the most effective weapons ever used by the police in their war against crime. No well-organized police system is considered fully equipped unless it possesses complete, efficient radiotelephone equipment for communications between headquarters and mobile police units.

The first police radio systems were developed to operate in the 1610- to 2490-kc. band. Amplitude modulation was used, and since the frequency of operation was just outside the broadcast band, standard a.m. broadcast transmitters were frequently used in these systems. The receivers in the mobile units were forms of standard a.m. automobile radios modified for the new frequency range and equipped with noise limiters and squelch circuits to minimize noise. Because of the limited number of frequencies available, and to minimize the possibility of image and cross-modulation interference of mobile units with standard broadcast receivers, this medium-frequency a.m. system was limited to one-way operation, from the fixed station to the mobile unit. This system has proved adequate in many communities despite its limitations.

Two-way communication systems have the distinct advantage of permitting quick confirmation and repetition of calls, rapid reporting, and much more efficient operation. This permits a police force to operate more effectively or to provide the same amount of protection with fewer police officers. Most modern police systems are therefore two-way.

The "talk-back" system from mobile unit to fixed station always operates at some frequency above 30 mc., where a large number of channels are available. Efficient, effective transmitters for operation in mobile units have been developed for this band of frequencies.

There are two general types of two-way systems. Some older police radio installations merely expanded their medium frequency a.m. "call" systems by adding a v.h.f. "talk-back" circuit. In one metropolitan system, for example, the fixed stations transmit on 2.422 mc. and the mobile units respond on 37.22 mc. This general system, incidentally, provides a degree of secrecy in that two receivers tuned to these widely different frequencies are necessary to hear both sides of this two-way system.

Other two-way systems, particularly power installations, use v.h.f. frequencies for both the "call" and the "talk-back" circuits. Generally the same channel is used for both circuits, although some systems use two separate channels. V.H.F. systems developed before about 1940 generally used a.m. Because of the noise- and interference-reduction properties of f.m., however, most of the newer police systems use f.m., and many older systems have been changed to it.

The present trend is to extend the frequency of operation from the present v.h.f. band of 37-46 mc. to the 72-76 mc. and 154-160 mc. bands. There are two reasons for this. First, although signals above 30 mc. do not ordinarily propagate very much beyond the horizon, unusual conditions sometimes permit reception in the 37-46 mc. band over long distances. There are instances, in fact, of a police call in one city being picked up by a police system on the same channel in another city several hundred miles away. Although this does not happen very often, it does occasionally cause interference, confusion, and annoyance that can be avoided by operating in the higher-frequency bands.

A second reason for preferring these higher-frequency bands is that there is a larger number of channels available in them.

In this Lesson we will study medium frequency a.m. police systems, 37-46 mc. a.m. and f.m. equipment used in police and other services, and equipment for the 72-76 mc. band. Although we will talk almost exclusively about police radio communications, you should keep in mind that the information given here applies to other services as well. The 37-46 mc. band, for example, includes some maritime mobile, forestry, ship emergency, power and petroleum, urban transit, fire, experimental, geophysical, and government service channels. This band is widely used by gas, water, electric, and transportation companies to direct their cars, busses, and street cars, and to improve the efficiency of maintenance and repair crews. The 37-46 mc. band also includes the highway mobile service of the telephone company.

In particular, the information given on police systems applies equally well to radio fire alarm systems. As a matter of fact, in cities of less than 150,000 population, the fire equipment is usually a part of the police communication system. This is advantageous in that it prevents duplication of equipment and coordinates police and fire activities.

However, cities with more than 150,000 population may have separate fire alarm radio systems. This service is assigned certain channels in both the medium-frequency and v.h.f. bands used in police services. The equipment used is the same as used in Police communication systems.

Propagation in the Police Radio Bands

Before we start our study of police radio systems, let us study the propagation characteristics of the two bands (medium-frequency and v.h.f.) used for mobile telephonic or voice communication services. We will consider only the propagation along the ground, because we are concerned

only with short-haul transmission, where dependable, reliable communication is wanted and skip-distance transmission is undesirable.

The relationship between field strength and distance for a 100-watt transmitter operating at the lower carrier frequencies of 1500 kc., 2000 kc., and 3000 kc. is shown in Fig. 1. A transmitting antenna of average characteristics (approximately equal to a quarter-wave vertical antenna) is assumed.

A similar graph for a 100-watt transmitter operating at carrier frequencies of 30 mc. and at 42 mc. is given in Fig. 2. A vertical half-wave transmitting antenna with its center supported 100 feet above ground level is assumed. For a flat terrain, there is no substantial difference in the attenuation of field intensity with distance for this frequency band in different parts of the United States.

For the purpose of comparison, Fig. 3 shows the carrier powers required to produce a field strength of 50 microvolts per meter at different distances from the transmitter. This shows clearly that the range of the very-high frequencies does not depend much on the power used; very little is gained in distance by stepping up the transmitter power. (However, high r.f. carrier powers are used in mobile communication systems to obtain high signal-to-noise ratios.)

Other differences in ground wave propagation in these two bands of frequencies are:

1. At very-high frequencies, the field strength at the receiving point increases directly with the height above ground of either the transmitting or receiving antenna. At the lower frequencies, on the other hand, height above ground of the transmitting or receiving antenna has little effect upon the field strength at the receiving point. In fact, the radiated pattern approaches the estimated pattern more closely and the sky

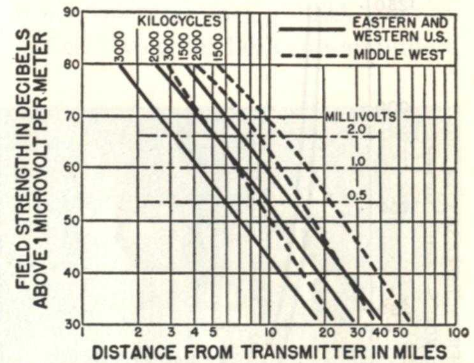


FIG. 1. The field strength of a typical 100-watt police radiotelephone transmitter at various distances from the transmitter is given here for three operating frequencies, 1500 kc., 2000 kc., and 3000 kc. The range of a transmitter of this size depends upon its location to some extent, the coverage being somewhat greater in the Middle West (dash-dash lines) than along the two coasts. The average modern police radio receiver requires approximately .5 millivolt per meter for a satisfactory signal.

wave is better controlled when the radiator rests on the ground. Control of the sky wave is desirable at these frequencies because this wave can cause serious interference hundreds of miles beyond the normal service range. An antenna that radiates very few high-angle lobes, meaning one with an electrical height of ¼ to ½ wave, or 150-250 feet, is best.

2. In the lower frequency band, the field strength varies approximately

inversely as the distance for a given power and transmitting antenna. At the very high frequencies, the field strength varies inversely as the square of the distance.

3. Atmospheric static interference is much more severe on the lower-frequency (1500 to 3000 kc.) police band than on the very-high frequencies. On the other hand, man-made interference, such as ignition interference from passing motor vehicles, is more severe in the v.h.f. police band. (This is not necessarily true if f.m. transmission is used, as you learned in earlier Lessons.)

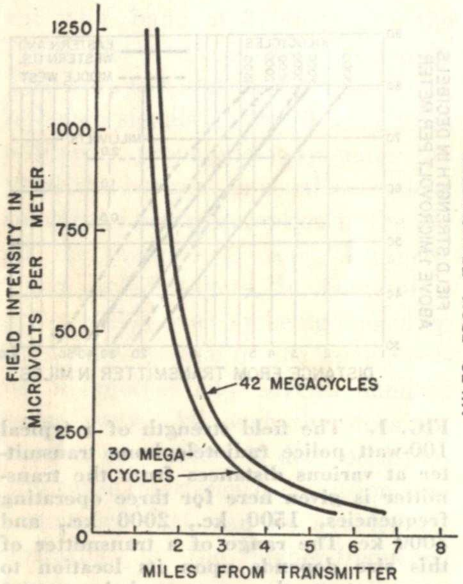


FIG 2. The field strength curves for a 100-watt transmitter operating on frequencies of 30 megacycles and 42 megacycles are given here. Note that the higher operating frequency gives a slightly stronger signal at a given distance from the transmitter.

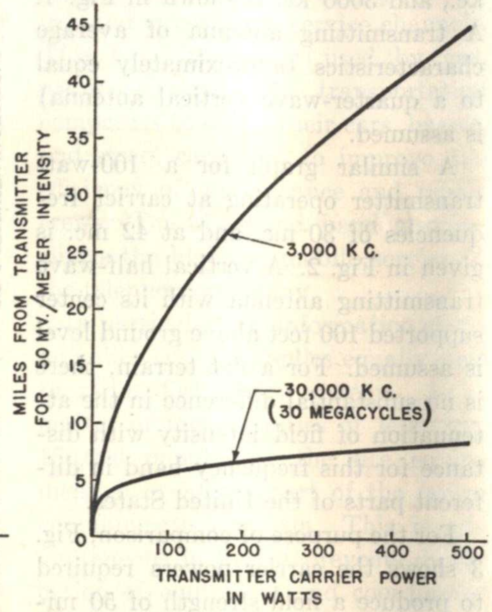


FIG. 3. The carrier power required to produce a field strength of 50 microvolts per meter at various distances from the transmitter can be determined from this chart for each of the police bands. Note the limited distance propagation in the ultra-high-frequency band.

Medium-Frequency A. M. Systems

In the one-way a.m. system, central transmitting equipment is installed at police headquarters (or at one or more precinct stations), and police patrol vehicles equipped with radio receivers cruise over assigned areas, ready to speed to any scene of crime in response to radio instructions from the transmitting station. This system has proved entirely adequate in many localities.

The one-way systems generally operate in the lower frequency range, 1610 kc. to 2490 kc. The power used at the transmitting station ranges from 50 to 500 watts, depending upon the area to be served. According to the regulations of the Federal Communications Commission, municipal police stations may have a radiated power of 50 watts in localities having a population of 100,000 or less, 100 watts in communities of between 100,000 and 200,000 inhabitants, and an additional 50 watts for each 100,000 increase in population to a maximum of 500 watts for an area with a population in excess of 700,000. State police systems use 500 watts where reasonably large areas must be served. In a number of the very large cities, such as New York, Chicago, and Philadelphia, several 500-watt transmitters are installed at suitable locations to cover the territory involved.

TYPICAL A. M. POLICE TRANSMITTING SYSTEM

An example of a medium-frequency a.m. police radio transmitter system is illustrated in Fig. 4, which is a block diagram of the Nassau County, N. Y., a.m. central control system.

Two operating positions are provided, which can be used either separately or together. All equipment shown is made by Western Electric. The dynamic microphones are the model 633A "salt shakers," each of which operates into a 116A pre-amplifier. Two other 116A pre-amplifiers, each with its output connected in phase to its input to produce audio oscillations, are used for tone signalling. Where selective ringing is not used for signalling, a tone has been found very effective for attracting attention.

The audio and tone signal are applied to a 119A amplifier and, through a pad, to the 443A-1 transmitter.

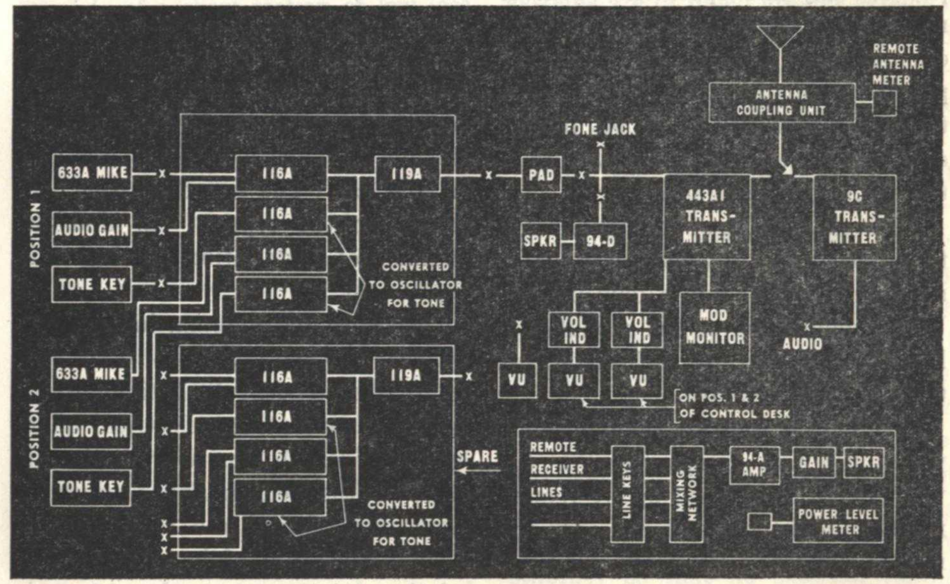


FIG. 4. A block diagram of the a.m. transmitting system used by the Nassau County, N. Y. police system. Western Electric equipment is used throughout. Note that the transmitter is a 443A-1 which is a standard a.m. broadcast transmitter.

A duplicate amplifier assembly is provided as a spare for emergency use.

The transmitter used is a standard a.m. broadcast type. This is typical of medium-frequency installations, because most broadcast transmitters can easily be converted to permit operation at frequencies up to 2500 kc.

The 443A-1 has a 1000-watt output for daytime operation. This is reduced to 500 watts at night to reduce possible interference with other police systems in other locations. In this particular system, a 9C broadcast transmitter (an older type than the 443A-1) is used as a spare.

Aural monitoring of the signal being transmitted is provided by a 94-D monitor amplifier and a loudspeaker. Visual monitoring of the modulating level is provided by VU meters at the operating positions.

The signals from the mobile units, which use f.m. transmitters in the v.h.f. band, are picked up by remote receivers and then fed by lines to the mixing network. Four remote unattended receivers are used for complete coverage of the county. The output of the mixing network is applied to a 94A monitor amplifier and to a monitor speaker.

REQUIREMENTS FOR MOBILE RECEIVING SETS

A radio set for police mobile service in either of the frequency bands, like any car receiver, must be extremely sensitive. As a matter of fact, the sensitivity required of a police receiver is considerably more than that needed for an ordinary car receiver, because satisfactory reception must be secured when the scout car goes under bridges, between steel buildings, or through other so-called "dead pockets."

The receiving antenna is usually limited in effective height; therefore, the problem of providing an efficient receiving antenna on the average automobile is quite a difficult one. When the entire body is of steel construction, as is the case with modern cars, an enclosed antenna is practically out of the question. The best installation for both medium frequencies and very-high frequencies is a flexible steel rod mounted at the rear of the car. The exact location depends on the type of car and the manner of installation of the radio equipment.

The steel-rod antenna increases in efficiency when v.h.f. is used, because the physical dimensions of the antenna approach an electrical quarter-wave length. In two-way installations, the rod antenna serves as both transmitting and receiving antenna. For the v.h.f. band, the length of the quarter-wave rod antenna is only about 8 feet. A better signal-to-noise ratio could be secured if horizontally polarized transmission and a horizontal antenna could be used. However, vertical antennas are the only type it is convenient to install and use on mobile units for the 37-46 mc. band because of the size needed; consequently, vertically polarized transmission is used.

A number of different methods have been used to connect the antenna to the receiver. Any shielded lead-in is satisfactory at the lower frequencies,

but, at the higher frequencies, the impedance of the antenna must be matched to the input impedance of the receiver to eliminate excessive losses, particularly if the length of the lead-in becomes an appreciable fraction of a wave length. A quarter-wave antenna presents a low impedance to the receiver input terminals; the input impedance of the receivers is accordingly designed to be low. Under these conditions, the lead-in consists of a short section of low-loss concentric cable.

The requirements for receiver selectivity are also strict, particularly for operation in the lower-frequency band. Besides the ordinary selectivity required in any receiver to keep out interference from stations operating on adjacent frequencies or on "image" frequencies, further selectivity is needed to prevent cross-modulation in the input circuits by powerful fields from stations such as broadcast stations (operating on any frequency) that the scout car may pass during its travels.

Automatic volume control is required in a.m. systems to take care of the wide variation in signal strength encountered. A.V.C. action should be fast in the v.h.f. receiver to compensate for the extremely sudden changes in signal strength that may be encountered by a mobile unit as it moves about.

The receivers are all designed with squelch circuits that keep the receiver sensitivity low until the squelch circuit is actuated by the desired carrier. This eliminates noise during the periods between transmissions. Carrier noise suppression is another common feature.

The audio frequency output must be sufficient to give satisfactory loudspeaker operation when the police car is traveling at high speeds in the outskirts of the region patrolled.

Economy of power is essential in a police car receiver to minimize drain on the automobile storage battery, which is the central source of power. Storage batteries used with mobile systems are of much greater capacity than ordinary car batteries, and charging generators are specially designed heavy duty units; even so, the power they can furnish is limited.

Since the police radio system for any one city is a fixed frequency service, the usual police receiver is permanently tuned to a given frequency and must remain in accurate tune under all conditions of operation. It is equipped with a remote control unit, but this device is used only to turn the set off and on and to control the volume. Special attention must be given to the local oscillator tuning circuits to provide proper frequency stability so that no external tuning control is required. The receiver circuits must be rendered immune to temperature and humidity changes.

From a mechanical viewpoint, the receiver must be ruggedly built, suitably shock-mounted to withstand the usual shocks and vibration during road use, and easily removable from its mounting for inspection and servicing.

Extensive precautions must be taken to prevent interference caused by the car from affecting reception. Interference from the car's ignition system is eliminated through the use of a shielded ignition "harness" (wire) or by installing suppressor resistors at each spark plug and at the common point on the distributor. A suppressor installation is shown in Fig. 5.

Another source of interfering noise is wheel static. This is caused by the friction of the rubber tire on the road, which builds up a charge that cannot drain off to ground because the wheel is insulated from ground by the

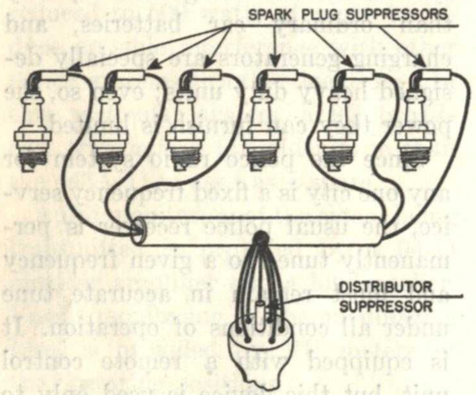


FIG. 5. Ignition noise suppressors as used in mobile units. These suppressors eliminate much of the impulse noise produced by electrical sparks.

rubber tire and by the grease surrounding the axle. Grounding the shaft to the frame of the car will eliminate the noise.

Bonding the body to the frame and the floating axles to the frame with flexible bonding braid and using condensers to bypass all parts in the electrical system that tend to develop voltage differences will go a long way toward the elimination of car noise.

The precautions just mentioned are extremely effective in keeping down the noise level in a.m. receivers. They are not as effective for f.m. receivers, however, although they do help.

MEDIUM-FREQUENCY A. M. RECEIVER

We will now study a typical mobile, medium-frequency a.m. receiver, the Motorola B-19-24-A. Its schematic diagram is given in Fig. 6.

This receiver is an eight-tube superheterodyne. It differs principally from an ordinary car radio in that it is fixed-frequency crystal-controlled and has noise-control circuits. The noise control consists of a series-type amplitude noise limiter and intertransmission noise suppressor (squelch) circuits.

This receiver can be set to any one frequency in the 1550-kc. to 3000-kc. region, which includes the band used for police services. It has an i.f. of 262 kc.; in the lower range of frequencies, the crystal oscillator is 262 kc. higher than the incoming signal; in the higher range it is 262 kc. lower than the signal.

The input r.f. coil T_1 has two primary windings to permit connection to either a high-impedance or a low-impedance antenna. The r.f. amplifier stage uses a 6K7 tube (VT_1). The output of this stage is coupled by L_1, L_2, and C_1 to the fourth grid of the 6A8 tube (VT_2) in the oscillator-mixer stage.

The first and second grids of this tube are used with a crystal in a Pierce crystal oscillator circuit. The difference frequency between the oscillator and incoming signal is applied through T_2, C_2, and T_3 to the i.f. amplifier stage, which uses a 6K7 tube (VT_3). Two double-tuned transformers are used here for high selectivity and image rejection.

The output of the i.f. amplifier is

coupled by T_4 to the detector-a.v.c.-squelch circuit, in which a 6R7 tube (VT_4) is used. The lower diode plate in this tube is used as a shunt rectifier to produce an a.v.c. voltage across C_3 that controls the gain of the first three stages of this receiver. Since R_1 is 1 megohm and C_3 is .03 mfd., the time constant is short, providing the quick-acting a.v.c. needed. In the absence of a signal, this diode plate is (because of C_4) at ground potential, but the cathode of the 6R7 is at a positive potential because of the drop across cathode resistor R_2. Thus, the lower diode plate will conduct and produce an a.v.c. voltage only when the input r.f. is higher than the voltage across R_2. This delayed a.v.c. action permits the receiver to be very sensitive when receiving weak signals, since the a.v.c. will cut down the gain of the set only when the input signal is large.

The output of the i.f. stage is also applied to the upper diode plate of VT_4. The d.c. level of this plate is the same as that of the cathode of the tube, so there will be detection for any value of input signal. When a signal is received, an audio signal is produced across R_3 and R_4 by this detection. There is also a d.c. voltage across R_3 that is proportional to the carrier strength.

Normally, the combined voltages developed across R_3 are great enough to cause the duo-diode VT_7 to conduct, thus permitting the audio signal to be applied through it to C_5 and R_5, the volume control. The audio signal is amplified by the triode section of the 6Q7 (VT_5), and then, through phase-inverting autotrans-

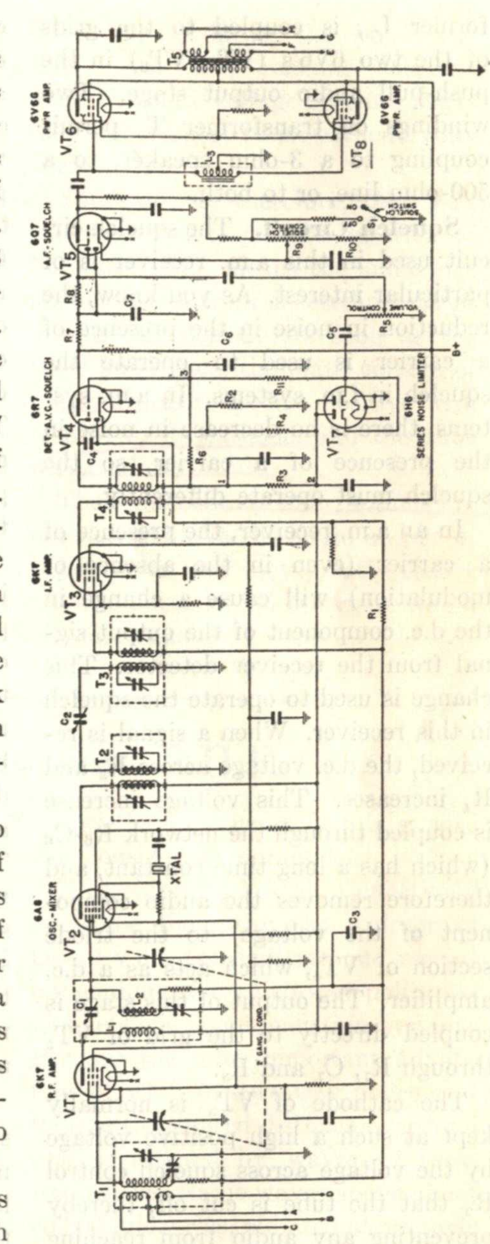


FIG. 6. Schematic diagram of the Motorola B-19-24-A receiver designed for a.m. mobile services in the 1550-3000 kc. band. It has many features typical of receivers for these services. Stable single-frequency operation is obtained by a crystal-controlled oscillator. T_2 and T_3 provide good image rejection. The 6R7, 6Q7, and 6H6 provide noise limiting and squelching.

former L_3, is coupled to the grids of the two 6V6's (VT_6, VT_8) in the push-pull audio output stage. Two windings on transformer T_5 permit coupling to a 3-ohm speaker, to a 500-ohm line, or to both.

Squelch Circuit. The squelch circuit used in this a.m. receiver is of particular interest. As you know, the reduction in noise in the presence of a carrier is used to operate the squelch in f.m. systems. In a.m. systems, there is no decrease in noise in the presence of a carrier, so the squelch must operate differently.

In an a.m. receiver, the presence of a carrier (even in the absence of modulation) will cause a change in the d.c. component of the output signal from the receiver detector. This change is used to operate the squelch in this receiver. When a signal is received, the d.c. voltage across R_3 and R_4 increases. This voltage increase is coupled through the network R_6-C_6 (which has a long time constant, and therefore removes the audio component of the voltage) to the triode section of VT_4, which acts as a d.c. amplifier. The output of this stage is coupled directly to the grid of VT_5 through R_7, C_7 and R_8.

The cathode of VT_5 is normally kept at such a high positive voltage by the voltage across squelch control R_9 that the tube is cut off, thereby preventing any audio from reaching the output stage. In the absence of an input signal, the triode section of VT_4 is biased only by the drop across R_2; its plate current is therefore high and its plate voltage low. The d.c. voltage applied through R_7, C_7, and R_8 to the grid of the triode section of VT_5 is therefore also low. However, as we just said, the voltage across R_3 and R_4 increases when a carrier is received. This voltage, which is negative with respect to ground, is applied to the grid of VT_4 through R_6, increasing the bias and therefore decreasing the plate current and increasing the plate voltage of VT_4. The increase in plate voltage of VT_4 causes a corresponding increase in the d.c. grid voltage on VT_5. This action brings the cathode and grid d.c. potentials closer together and permits the tube to amplify, removing the squelch.

The amount of squelch can be adjusted by varying R_9. The diode plates of VT_5 are used to prevent excessively strong signals from causing the grid of VT_5 to go positive with respect to its cathode. Switch S_1 can be used to shunt R_9 and R_{10}, reducing the cathode voltage on VT_5 and making the squelch inoperative. Thus, the squelch can be removed without altering the setting of the squelch sensitivity control (in other sets, it is often necessary to readjust the squelch sensitivity control to remove the squelch, and to reset it again when squelch action is desired).

Noise Limiter Action. The audio signal in this Motorola receiver normally passes through VT_7. Noise limiting is secured by an arrangement that makes this duo-diode tube cease conducting for the duration of the noise pulse, thus blocking the audio signal.

Let us study this action in detail. When a signal is being received, there is a voltage drop across R_3, with point 1 negative with respect to point 2. Since point 2 is connected directly to the plate of VT_7, and the cathode of VT_7 is connected to point 1 through R_6 and R_{11}, VT_7 will conduct when a normal signal is present. Point 3 will be maintained at a constant d.c. voltage because the time constant of R_6 and C_6 is long (0.1 second—C_6 is a 0.1 mfd. condenser).

Let us assume, however, that a sudden burst of noise is received. This will cause the voltages at points 1 and 2 to increase suddenly, that is, become more negative with respect to ground. Because condenser C_6 is too large to discharge appreciably during the noise pulse (which may last only 1/1000 of a second), the voltage at point 3 will remain essentially constant. Thus, during the pulse, the cathode of VT_7 remains constant while the plate voltage becomes negative with respect to its cathode voltage.

You can see, therefore, *that VT_7 will not conduct for the duration of the pulse.* This means the audio signal is cut off from succeeding stages during this period. As soon as the noise pulse ends, the plate voltage of VT_7 will again become positive with respect to its cathode, and the tube will conduct.

These momentary interruptions are not noticeable in the audio output of the receiver, but they greatly reduce impulse noise, which otherwise would be quite annoying.

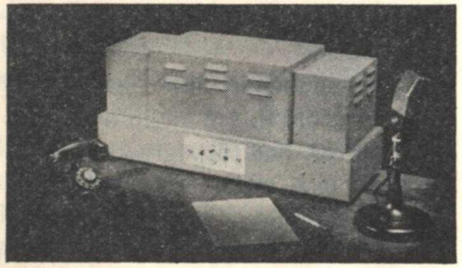
A.M. Systems for V.H.F.

In spite of the proved effectiveness of the one-way system, it has, as you learned earlier, several operational limitations. It was recognized in the early days of police radio that increased efficiency would be obtained if the patrol vehicles could communicate directly with headquarters at any time. Among the advantages seen for a two-way communication system were that it would allow patrol cars to acknowledge orders or ask for repeats, thereby preventing otherwise unavoidable mistakes, and that it would keep headquarters (and other pursuit cars) informed of new developments during the pursuit of escaping criminals. However, the addition of numerous mobile transmitters in the already overcrowded low-frequency band assigned to this service was considered impractical.

This objection has been effectively overcome today by the widespread use of v.h.f. transmitting and receiving equipment for two-way police radiotelephone communication systems. Perhaps the most important advantage of v.h.f. for two-way police systems is the limited distance over land that is covered by waves of these frequencies. Radio waves above about 30,000 kilocycles, radiated at an angle to the earth's surface, generally leave the earth entirely instead of being reflected back by the ionosphere.* Interference from distant stations in an adjacent or in the same frequency channel is thus largely eliminated.

* Ionized layers existing at heights of about 70, 140 and 280 miles above the earth's surface.

Many municipalities have installed two-way systems using v.h.f. equipment operating somewhere in the 37-mc. to 46-mc. band. The transmitting power used at the central stations in v.h.f. two-way systems ranges from 5 watts in the case of the smallest municipalities to 250 watts for the larger cities. The mobile transmitters usually radiate 5, 10, or 25 watts of carrier power.



Courtesy General Electric

An example of an ultra-high frequency a.m. station transmitter is the General Electric G-12 shown here. This completely self-contained unit includes power supply, speech amplifier, modulator, and r.f. units. It has an r.f. power output of 25 watts in the 37-46 mc. band. The r.f. circuit consists of a crystal oscillator and harmonic generator stage, doubler, and final power amplifier stage. The audio circuit has three speech-amplifier stages, a tone generator (for signaling) and a class AB modulator stage.

Do not assume, however, that v.h.f. systems have rendered lower-frequency systems obsolete. There are many police systems and services for which v.h.f. propagation, with its limited distance range, is not suitable. For example, in the case of state police systems, the distances involved are such that they cannot be efficiently covered on the very-high frequencies. Again, it is frequently necessary to have communication between police systems of different cities that are separated by considerable distances. The lower-frequency band must generally be used in such services.

In a number of installations, it has been found advisable for the central station to transmit in the lower-frequency band to police cars and to other police radio systems, but to use v.h.f. transmitters in the police cars. In this "mixed" system, the central station equipment includes both low and high-frequency receivers, and the police cars carry low-frequency receivers.

REQUIREMENTS FOR MOBILE POLICE TRANSMITTERS

The requirements for the mobile v.h.f. transmitters used in police cars for communicating with the central station are particularly severe.

The first requirement is that the carrier frequency of the transmitter must be held within very close limits. Thus, crystal control of the carrier frequency is necessary.

Economy of power consumption is even more important for a mobile transmitter than for a receiver because of the greater amount of power required by the former. A storage battery supplies filament voltage, and operates the dynamotor or vibrator that supplies B and C power. Proper design of the speech amplifying and modulating system is quite important to obtain efficient operation.

Mechanical ruggedness of the component parts is also essential.

Carbon microphones are widely used in mobile services because of their high-level output and because they are mechanically very rugged.

Since quite a few v.h.f., a.m. systems are still in operation, let us now study typical transmitters and receivers for this service. (We will take up the most recent system—v.h.f. using f.m.—a little later.)

MOTOROLA T-69-20A TRANSMITTER

This transmitter, designed to provide 15 watts of a.m. signal in the 37-46 mc. band, is shown schematically in Fig. 7.

One half of the 6F8G tube is a conventional crystal oscillator that operates on ¼ the desired output frequency. A crystal oscillator is used to provide the frequency stability required by the FCC. The crystal oscillator output is coupled through C_6 to the 6L6G quadrupler stage. This signal is then applied to the RK39/-807 final amplifier stage. Because of the possibility of parasitic oscillation in the v.h.f. band, a suppressor network LR_1 is used. The values of L and R_1 are not given, because they depend on the actual values of the components and the characteristics of the tubes used.

The output coupling used in this circuit is unusual. The conventional method of impedance matching to the antenna from a tap on L_3 is not followed; instead, the coil is untapped and the output is coupled from the normally "dead" end of the coil. However, this end of the coil is not at ground potential, because C_{16} and

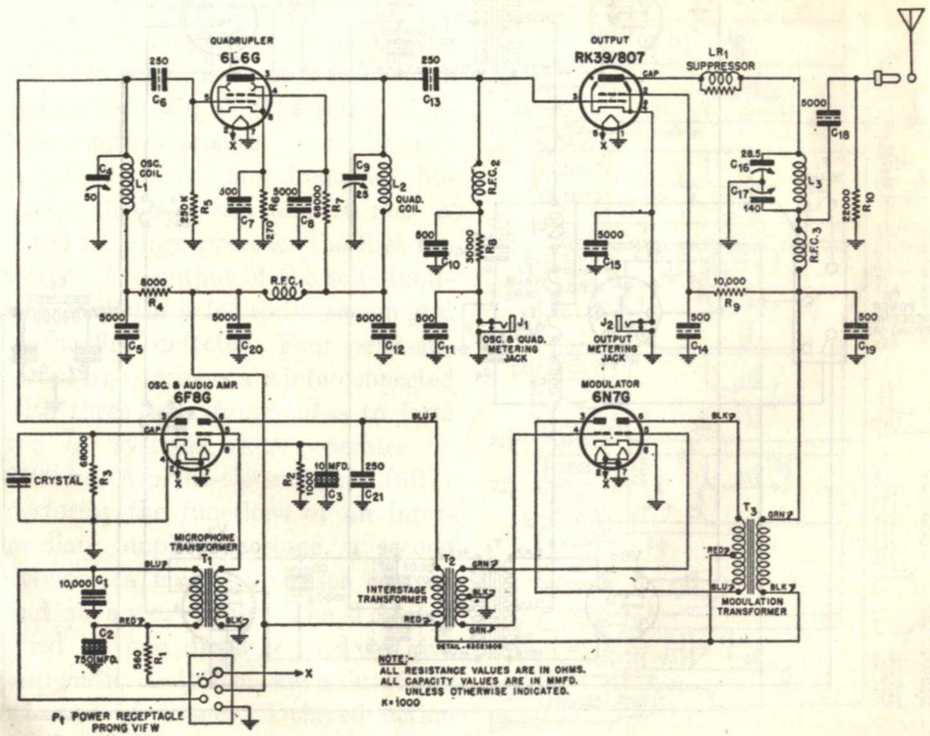


FIG. 7. Schematic of the transmitter unit of the Motorola T-69-20A. This typical v.h.f., a.m. transmitter operates in the 37-46 mc. band with 15 watts output and is used by police and other mobile services. The crystal oscillator operates on ¼ the output frequency.

C_{17} form an r.f. voltage divider, with the ground connected to the common connection between C_{16} and C_{17}. Thus, the r.f. voltage across C_{17} is fed to the antenna.

The audio section starts with a single-button carbon microphone coupled to the other half of the 6F8G tube through microphone transformer T_1. The output of this stage drives the 6N7G modulator, which is a zero-bias class B audio stage. The output plate-modulates the 807 tubes through T_3.

Power Supply. The schematic of the power supply for this transmitter is shown in Fig. 8. Two vibrator power supplies in parallel are used to provide the necessary current.

Relay RY_1 is used to control the 6-volt d.c. input to the two power supplies. Normally terminal 3 of this relay is connected to terminal 4 by the relay armature; this permits C_8 to discharge through R_1. However, when the push-to-talk button on the microphone is depressed, the relay coil (between terminals 1 and 5) is energized; the armature then connects terminal 3 to terminal 2, thus grounding contact 1 on each of the vibrators VB_1 and VB_2. This causes the vibrator "motors" to operate, thus producing a.c. voltages that are recti-

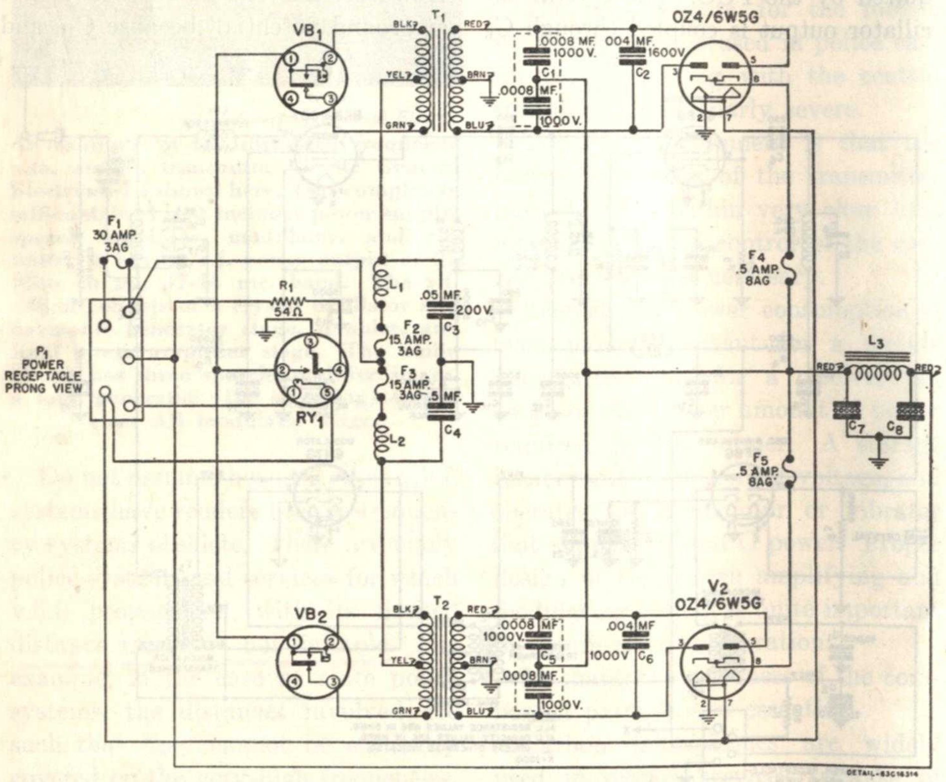


FIG. 8. The dual vibrator power supply used to operate the Motorola T-69-20A transmitter. One vibrator alone is not capable of supplying the power needed for this transmitter. Relay RY_1 is operated by the PUSH-TO-TALK button to turn on both sections of this power supply.

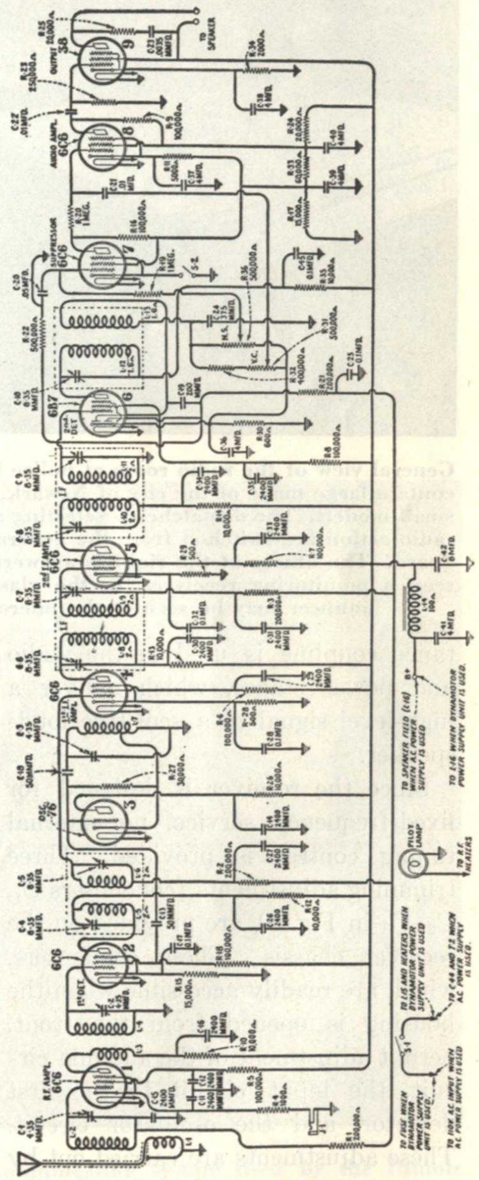
fied by V_1 and V_2. When the push-to-talk button is released, relay RY_1 disconnects VB_1 and VB_2.

As the diagram shows, the tubes may be either 0Z4 (cold cathode) or 6W5G (filament type) tubes — they are directly interchangeable. The cold-cathode tubes are used when economy of filament power is particularly important, even though they tend to be noisier than filament rectifiers.

The total filament drain of the transmitter with 6W5G tubes is 5 amps., with OZ4's, 3.2 amps. The current drain when transmitting is about 18 amps.

RCA TYPE AR-5019 V.H.F. MOBILE RECEIVER

A circuit diagram of the RCA Type AR-5019 v.h.f., a.m., mobile receiver is shown in Fig. 9. The set, a nine-tube superheterodyne, can be adjusted to receive any frequency between about 37 mc. and 46 mc. A tuned r.f. stage precedes the first detector. The output of the self-stabilized oscillator is fed to the screen grid of the first detector. Four peak-adjusted transformers are interconnected with three amplifying tubes to form the i.f. system, which operates on 2100 kc. A multi-element tube (6B7) performs the functions of an intermediate amplifying stage, a second detector, a noise suppressor control, and an a.v.c. supply. The d.c. supplied by one diode is used to give automatic control of the gain of the r.f. and i.f. stages. Delayed action results from the presence of an initial negative bias on the a.v.c. diode plate. The d.c. resulting from signal detection on the other diode plate is applied to the control circuit of the type 6C6 noise-suppressor tube. The a.f. portion of this voltage is fed to the first audio amplifier through the volume control arm. Resistance-capaci-



Courtesy RCA Mfg. Co.

FIG. 9. Circuit diagram of RCA type AR-5019 ultra-high frequency police receiver.

Courtesy Western Electric

General view of the radio room at police headquarters, Newark, N. J. The two tables contain large maps of the city of Newark, on which the radio cars are represented by small models. The dispatcher is selecting a car to answer an alarm. All calls requiring radio action are switched from the general police telephone board to the radio room board. The officer at the right is answering such a call. Over his shoulder may be seen a monitoring receiver. In the glass-enclosed booth at the left rear, the announcer may be seen at the microphone putting an alarm on the air.

tance coupling is used in the audio and power stages, which deliver a high-level signal to a sensitive loudspeaker.

Since the receiver is designed for fixed-frequency service, no external tuning control is provided. Three trimming adjustments (condensers C_1, C_2, C_3 in Fig. 9) are provided on the receiver chassis. These condensers, which are readily accessible when the housing is opened from the front, permit adjustment of the antenna circuit, the input circuit to the first detector, and the oscillator circuit. These adjustments are carried out by maintenance men rather than by the police officers.

The oscillator is of a type that has proved particularly suitable for stable operation at very-high frequencies. It uses what is essentially a Hartley circuit with the plate at ground potential for r.f. This tends to reduce the effect of external component parts on frequency stability, because the plate element serves as a shield.

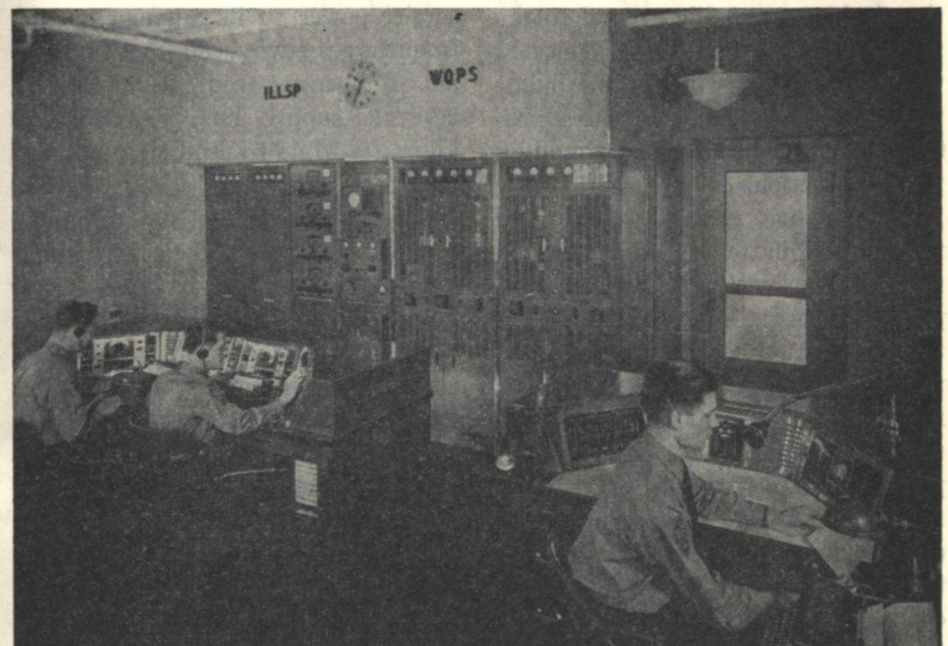
POLICE HEADQUARTERS EQUIPMENT

A good example of the general arrangement and typical use of the headquarters equipment required for either a one-way or a two-way police v.h.f. communication a.m. system is furnished by the Newark, New Jersey, set-up. Newark was among the first of the larger cities to adopt very-

high frequencies for police use. The equipment used, supplied by the Western Electric Company, is proving highly effective in the city's fight against crime. One-way communication only is provided, but the system may be expanded for two-way service through the addition of mobile transmitters on the police cars and a suitable receiver at the radio station.

Newark centralizes its radio dispatching in a large room at Police Headquarters. The announcer, who broadcasts orders to the receivers in police cars and precinct stations, sits at a desk in an enclosure at one side of the room. In the center of the room are two tables on which are large-scale maps of the territory covered. Miniature models of the police cars are placed on these maps in their last reported locations so that a glance shows which car is nearest the location of the crime. On the other side of the room is a small telephone switchboard at which all incoming calls are received. A fire-alarm tape recorder, also located here, immediately notifies the dispatcher of all fires. Adjacent to the radio dispatching room is the police teletype room, where messages are received in typed form from other police departments.

The radio transmitter is located in a room on the 34th floor of the highest building in Newark. This location was chosen because of the very favorable position for the transmit-



Courtesy Western Electric

Dispatching headquarters police radio communication system used by the Illinois State Police. The transmitter, test equipment, and various standby and monitoring receivers are located at the back of the room. At the left, two men monitor and record incoming messages while the dispatcher at the right issues the outgoing calls. This is a typical dispatching system for a large police organization.

ting antenna; height above the ground is of great importance in this installation, since the city is large and the transmission must therefore cover a wide area. Since dispatching is normally done from police headquarters, the transmitter is designed for remote control from that point. The dispatcher's microphone feeds into a speech amplifier and then over telephone lines to the input of the radio transmitter. A monitoring amplifier shows the dispatcher how the transmitter is operating.

The transmitting antenna, which has an effective length of one-half wavelength, is mounted on top of a 100-foot flag-pole on the roof of the building. The building itself is 600 feet high. The antenna is novel in that it has a metallic ground to the flag-pole, which in turn is connected to the steel framework of the building. This arrangement insures protection from lightning and simplifies the construction.

The antenna is a vertical bronze tube three-quarters wavelength (22 feet) long, projecting above the flag-pole. A coaxial (concentric type) transmission line connecting the transmitter output to the antenna is run up the inside of the flag-pole to the base of the antenna. At this point, the inner conductor emerges from the pole and continues for another quarter-wavelength parallel to the vertical bronze tube. The inner conductor and this section of the tube thus form a parallel-conductor quarter-wavelength transmission line. The upper half-wave portion of the bronze tube serves as the radiating antenna. The parallel-conductor transmission line serves as a quarter-wave transformer that matches the high impedance of the half-wave antenna (fed at its lower end) to the low impedance of the coaxial transmission line.

TYPE 16A V.H.F. HEADQUARTERS TRANSMITTER

The v.h.f. headquarters transmitting set used in the Newark installation consists of a Western Electric type 16A 50-watt transmitter and a 500-watt power amplifier. The 50-watt transmitter, when used alone, is capable of serving the average medium-sized city.

A circuit diagram of the type 16A transmitter is given in Fig. 10. This transmitter is crystal controlled and is capable of delivering 50 watts of carrier power to its antenna on any frequency between 30 mc. and 60 mc. It operates from a single-phase, 60-cycle supply line, requiring 1.2 kilowatts while transmitting and 0.55 kilowatts during stand-by periods. The set is designed to have minimum carrier frequency deviation, minimum distortion, and excellent speech intelligibility.

The r.f. unit contains the crystal controlled oscillator, a frequency multiplier stage, an r.f. amplifier, and a modulated amplifier. The oscillator operates at either one-fourth or one-sixth of the carrier frequency, depending upon the value of the carrier frequency. The output circuit of the modulated amplifier is designed to operate into a concentric transmission line.

The audio-frequency panel contains three stages of audio-frequency amplification, these being necessary to

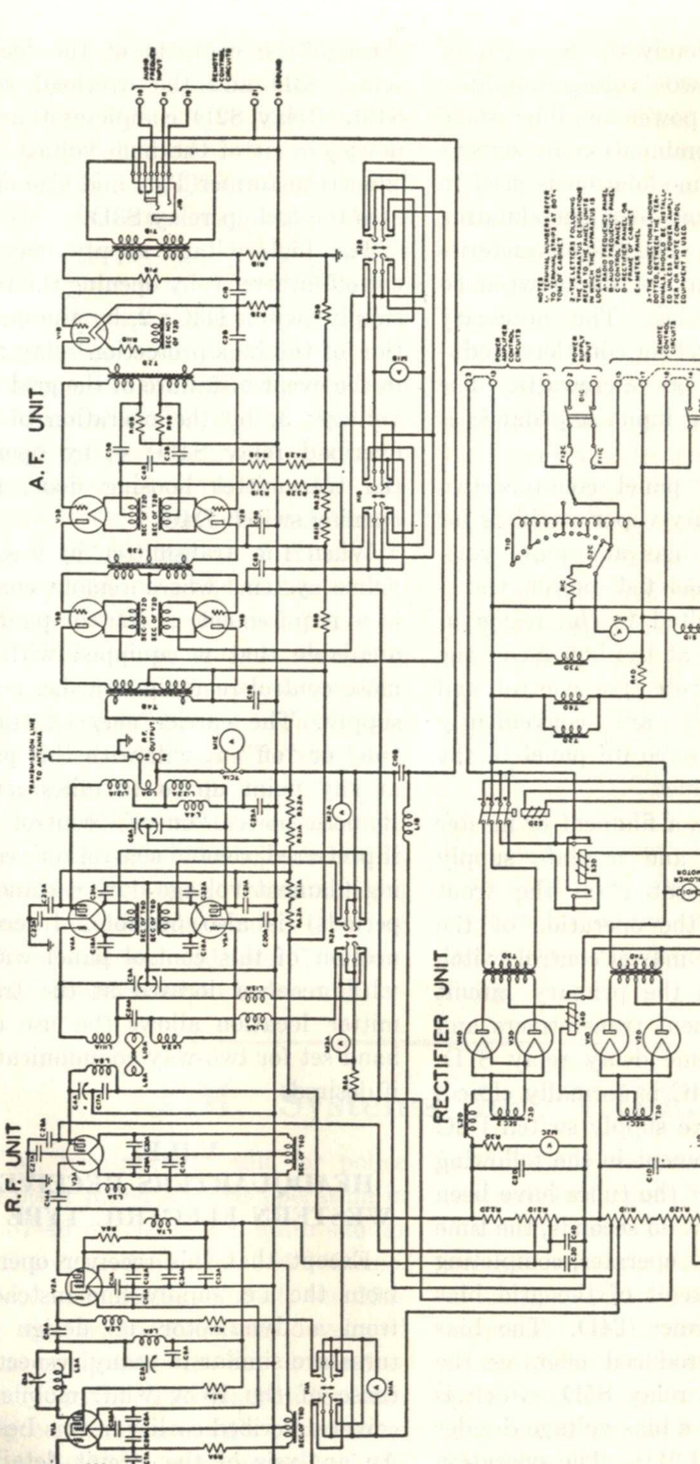


FIG. 10. Schematic circuit diagram of Western Electric type 16A 50-watt v.h.f. headquarters transmitter.

modulate completely the 50 watts of r.f. power. Two voltage-amplifier stages and one power-amplifier stage are used. A combination of screen-grid and plate modulation is used to reduce the amount of a.f. modulating power required. The a.f. characteristic is flat within ±1 db between 60 and 10,000 cycles. The necessary speech input level for complete modulation is only 60 microwatts. The speech amplifier input impedance is 500 ohms.

The rectifier panel contains two full-wave mercury vapor rectifiers for supplying grid bias and plate voltages. The associated power transformers are bolted to the frame of the transmitter at the bottom of the cabinet. All protective control and overload relays are conveniently mounted on a separate panel in the back of the cabinet.

Two switches, a filament or master control switch and a plate supply switch, both located on the front panel, control the operation of the equipment. The master control switch D1C completes the primary circuit to all the filament transformers and operates the time delay relay S1D. Door switch D4C is normally closed. Closing the plate supply switch D3C starts the equipment in the following sequence: After the tubes have been lighted for about 35 seconds, the time delay relay S1D operates, completing the primary circuit of the grid bias supply transformer T4D. The bias voltage thus produced operates the bias protection relay S5D, which is in series with the bias voltage divider (R1.1D and R1.2D). The operation of this relay operates relay S2D through the contacts of the lockup relay S3D and the overload relay S4D. Relay S2D completes the primary circuit of the high-voltage-rectifier transformer T5D and also operates the lockup relay S3D.

The high-voltage supply may be cut off either: 1, by opening the plate supply switch D3C; 2, by the operation of the bias protection relay S5D in the event of failure of the grid bias voltage; 3, by the operation of the overload relay S4D; 4, by opening the transmitter housing door, thus opening switch D4C.

When the transmitter is used in police systems where remote control is a requirement, a control panel is available that is equipped with remote control relays and a d.c. power supply. The carrier may be turned "on" or "off" at will with this panel at any point up to 10 miles away. Remote power "on-off" control (or, if preferred, remote control for reducing filament voltage during stand-by periods) is also possible. Interconnection of this control panel with a v.h.f. receiver located at the transmitter location allows the use of a hand set for two-way communication, if desired.

V.H.F.
HEADQUARTERS RECEIVER
WESTERN ELECTRIC TYPE 19

Except that this receiver operates from the a.c. supply line instead of from a dynamotor, its design features are similar in many respects to those of the RCA v.h.f. mobile receiver described earlier in this Lesson. An analysis of the circuit detail is, therefore, not necessary here.

The set uses seven tubes in a superheterodyne circuit, including a stage of r.f. amplification, a beat oscillator, a first detector, two stages of 3850 kc. i.f. amplification, a second detector, and an audio output stage. The receiver is provided with automatic volume control, separate manual volume control, and output level control. The a.v.c. operates so that a change of from 3 microvolts to 100,000 microvolts in the received voltage produces only a 3 db change in the audio output voltage. The sensitivity of the receiver is such that a v.h.f. input voltage of 2 microvolts will produce an audio output of 50 milliwatts. The selectivity is such that when the set is tuned to a carrier frequency of 35 mc. an interfering signal only 100 kc. away would have to be 1000 times as strong to produce equal output.

Novel features of this receiver include a crystal-controlled oscillator, permitting complete freedom from tuning adjustments, and a "carrier operated device anti-noise" (commonly abbreviated to codan and referred to as "silent a.v.c." in broadcast receivers), which insures relatively quiet conditions in the receiver output when the carrier to which the receiver is tuned is off the air. If desired, the first oscillator may be used as a self-excited type, with a vernier adjustment for occasional tuning.

The codan device is similar in operation to the other inter-carrier noise-suppressing circuits that you have studied. In the absence of a received carrier, a high voltage is automatically applied across a neon tube, making it conduct. The neon tube is connected to the audio amplifier circuit in such a way that the amplifier is made very insensitive, thereby killing the output, when the tube conducts. When a carrier is received, the voltage across the neon tube is reduced to such an extent that the tube becomes non-conducting. This removes the short-circuiting path in the audio amplifier, and the latter comes back to normal sensitivity.

F.M. Systems for V.H.F.

F.M. transmitters built for police and other allied services operating in the 37-46 mc. band are quite similar to those used in the 154-160 mc. band. As a matter of fact, the 154-160 mc. equipment was developed from equipment in the lower-frequency band. The transmitters are designed to operate with a frequency swing of ±15 kc., have an audio band pass of 250 cycles to 3000 cycles, and use phase modulation of a crystal-controlled r.f. oscillator.

Usually, for f.m. communication transmitters operating in the police or similar service bands, an over-all frequency multiplication of 32 is used. This requires a crystal frequency somewhere between 1156.2 kc. and 1437.5 kc., and an original frequency swing of ±.46875 kilocycles. These frequencies can be obtained.

and distortion can be held reasonably low, with comparatively simple phase-modulation circuits when the lowest a.f. signal voltage is 250 cycles or above.

MOTOROLA 37-46 MC. F.M. EQUIPMENT

A Motorola f.m. transmitter for the 37-46 mc. band is shown in Fig. 11.

The output of oscillator V_{101} is fed to the phasing section T_1, where the output of the single ended oscillator is first divided through a phase inverter circuit so that the r.f. voltages applied to C_3 and C_5 are in push-pull, that is, 180° apart in phase.

C_3 and C_6 each have a low impedance to r.f., so there is no phase shift in the grid voltages across R_4 and R_5 applied to V_{103}. However, C_5 is a smaller condenser and has appreciable

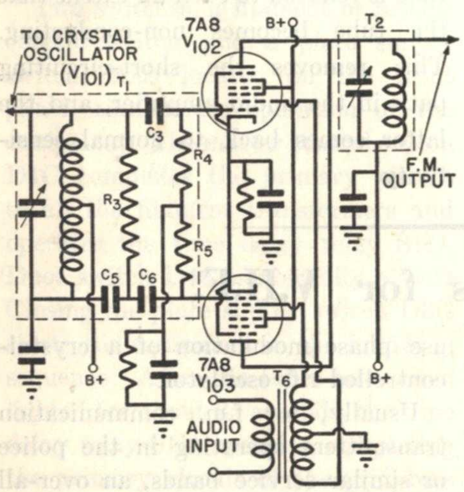


FIG. 11. The basic phase modulation method used in Motorola 37-46 mc. f.m. transmitters. The r.f. grid voltages applied to V_{102} and V_{103} are less than 180° out of phase so that out-of-phase amplitude modulation of V_{102} and V_{103} will cause phase modulation of the resultant r.f. output voltage.

reactance with respect to R_3. This produces a phase shift that causes the grid voltage applied to V_{103} to be less than 180° out of phase, about 165°, for example. Thus, although the plates are connected in parallel, the two r.f. voltages will not cancel.

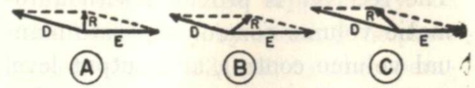


FIG. 12. How two r.f. voltages 165° out of phase and of varying amplitude will produce a resultant voltage R whose phase angle varies below (B) and above (C) the midvalue of 82.5° in (A).

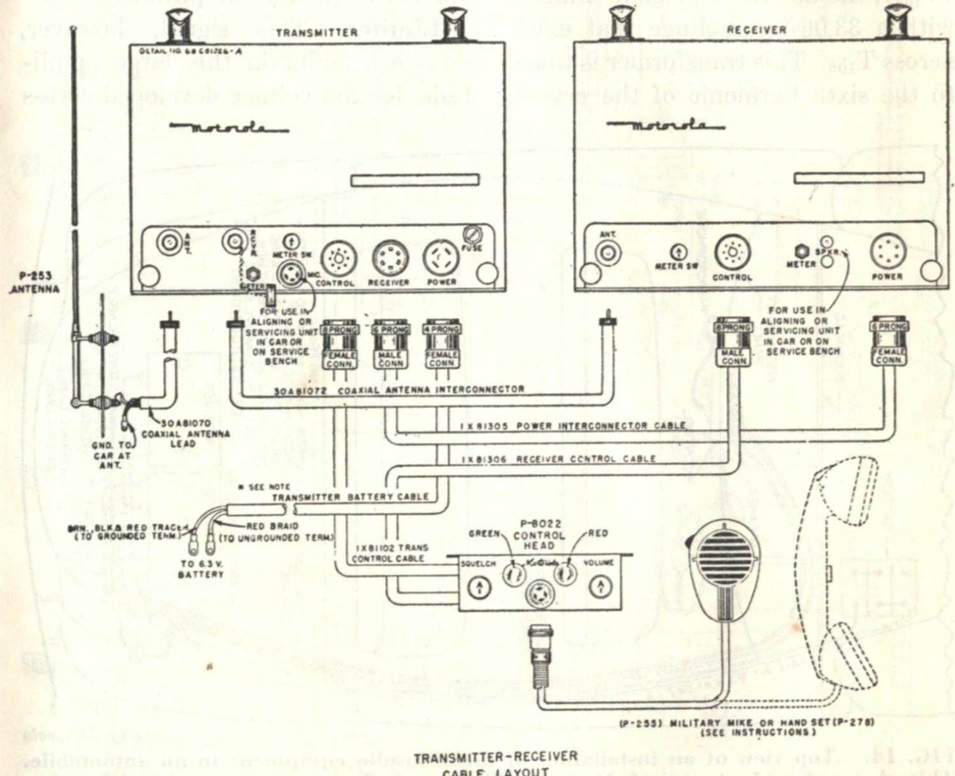
ages will not cancel. As you have already learned, and as Fig. 12 shows, the output r.f. is midway in phase between the grid voltages applied to the grids of V_{102} and V_{103} when the two voltages are equal. Let us say vector D is the grid voltage of V_{102} and vector E is the grid voltage of V_{103} at any given instant.

The modulating voltage is fed from the modulating transformer T_6 to the screen grids of V_{102} and V_{103} in push-pull (180° out of phase). This means that, at any one instant, the voltage from the modulating transformer will be negative on one screen grid and positive on the other. The tube with positive audio voltage on its screen grid will draw greater plate current than the tube with the negative audio voltage on its screen grid; this will cause an unbalance between the two r.f. voltages, and the phase angle of the resultant R will change, as shown in Fig. 12B. On the next half of the audio signal, this unbalanced condition will be reversed, and the phase angle of the resultant will change as shown in Fig. 12C. Phase shifts of ±82.5° are possible. These phase

shifts provide the necessary frequency deviation at T_2 of 468.75 cycles. With a frequency multiplication of 32, the output in the 37-mc. to 46-mc. band has a swing of fifteen kc. The frequency multiplication of 32 is achieved through the use of two quadruplers and one doubler.

is to take a figurative ride with the signal and observe the action in a typical receiver of this type. During this discussion we will refer to the schematic diagram of the General Electric receiver shown in Fig. 15.

R.F. Section. Suppose that the input is 39.025 mc. Beginning at the



Courtesy Motorola

FIG. 13. How the various units of Motorola 37-46 mc. f.m. mobile equipment are interconnected by cables. This type is frequently used in mobile police installations.

This mobile equipment is easy to install and requires a minimum of space. Figs. 13 and 14 show the cable connections of a two-way police cruiser installation.

V.H.F., F.M. RECEIVERS

Perhaps the easiest way to explain the operation of a v.h.f., f.m. receiver for operation in the 37-46 mc. band

antenna receptacle of the receiver, the signal voltage is first boosted by antenna input transformer T_{101}. The secondary of this transformer is tuned to resonance by a powdered-iron slug that can be screwed up and down inside the coil. This method of tuning is used everywhere in the set except in the discriminator.

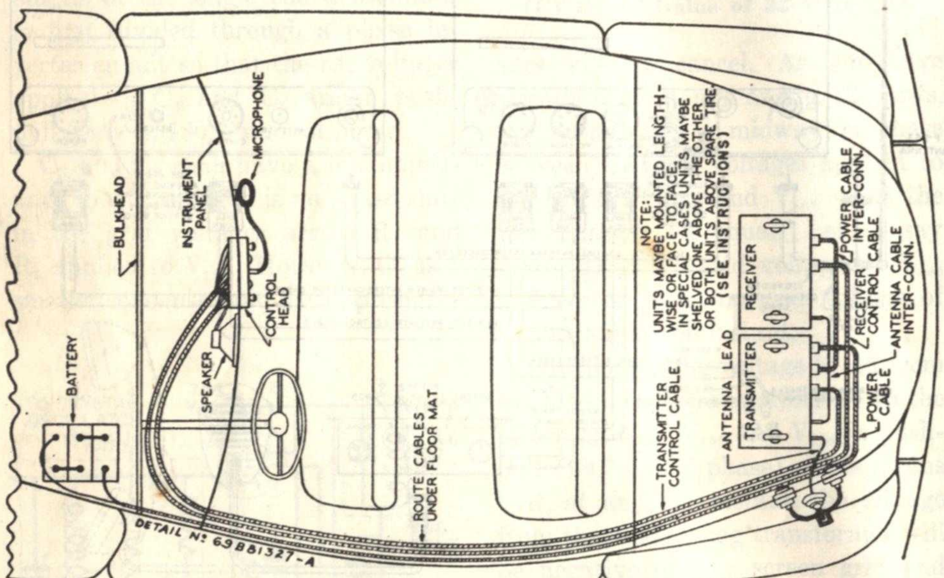
The signal passes then to the grid

of the 7AG7 r.f. amplifier tube (V_{101}), which amplifies the signal and impresses it on r.f. transformer coils L_{106} and L_{107}. Both primary and secondary of this transformer are slug-tuned to 39.025 mc. for maximum selectivity.

At the grid of the first converter (V_{102}), the 39.025 mc. signal is mixed with a 33.06-mc. voltage that exists across T_{106}. This transformer is tuned to the sixth harmonic of the crystal

through i.f. transformer coils L_{110} and L_{111}, and is there mixed with a signal of crystal frequency (5.51 mc). The 455-kc. difference frequency (5.965 mc. — 5.51 mc. equals .455 mc. or 455 kc.) is then passed on to the grid of the 455 kc. amplifier, where it is amplified until it has a rather large amplitude.

Limiter. This signal, however, does not maintain this large amplitude, for the voltage developed across

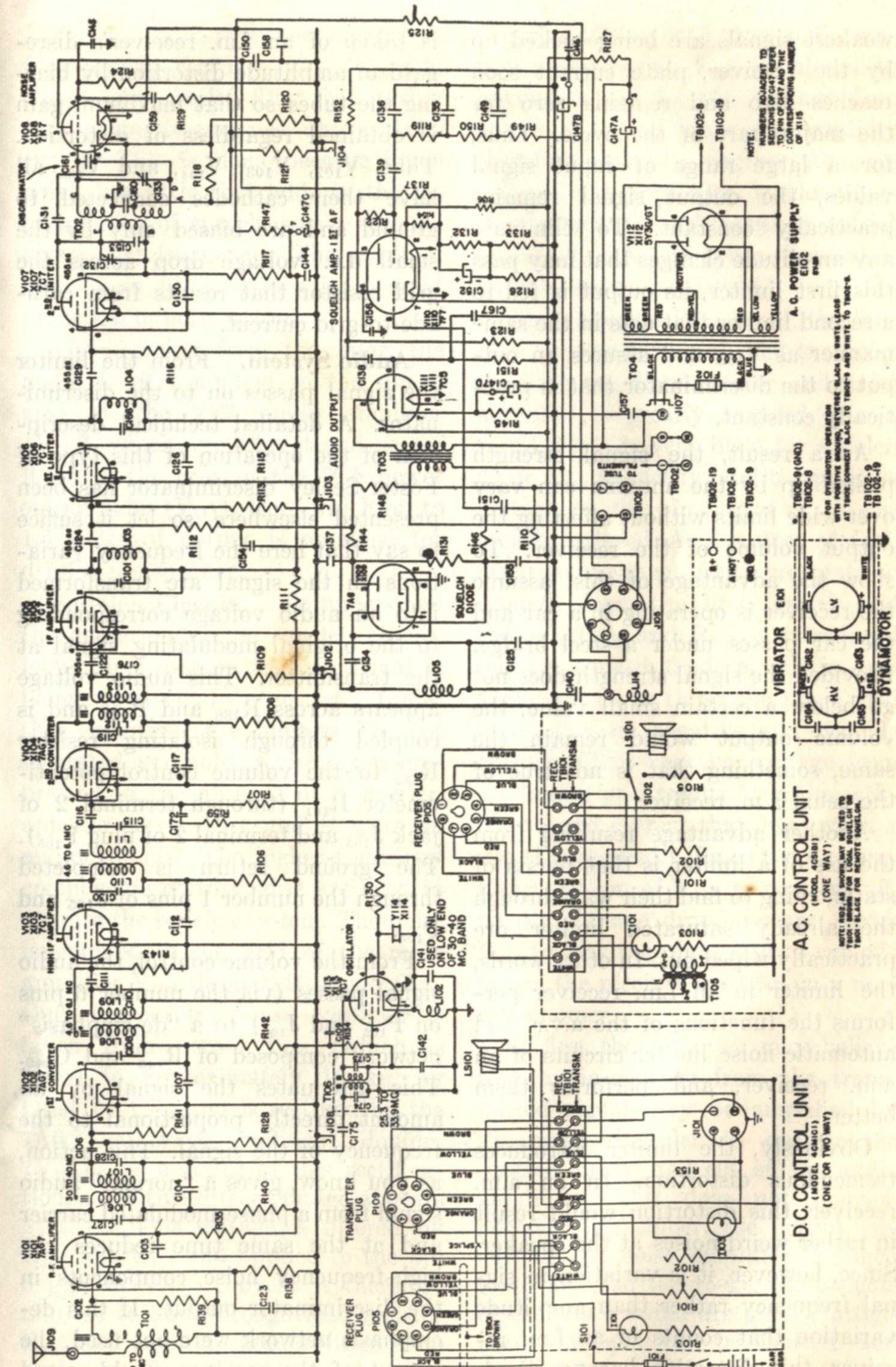


Courtesy Motorola

FIG. 14. Top view of an installation of mobile radio equipment in an automobile. This shows the placement of Motorola 37-46 mc., f.m. equipment although other installations may be similar.

frequency (5.51 mc.). The conversion product corresponding to the difference of the two input frequencies (39.025 mc. — 33.06 mc. = 5.965 mc.) is selected by the transformer consisting of L_{108} and L_{109} and is passed on to the grid of the high i.f. amplifier (V_{103}). After being amplified in V_{103}, the 5.965-mc. i.f. signal is applied to the grid of the second converter V_{104}

tank coil L_{103} is impressed on the grid of a limiter tube V_{106}. This tube operates with extremely low plate and screen voltages, and, as a result when the grid swings positive, plate saturation quickly occurs and the plate current remains practically constant for the larger part of the positive portion of the cycle. During the negative portion, when all but the



Courtesy General Electric

FIG. 15. Schematic diagram of the G. E. 37-46 mc., f.m. receiver.

weakest signals are being picked up by the receiver, plate current soon reaches zero and remains zero for the major part of the cycle. Thus, for a large range of input signal values, the output signal remains practically constant. To eliminate any amplitude changes that may pass this first limiter, its output is fed to a second limiter that acts in the same manner as V_{106} and assures an output to the discriminator that is practically constant.

As a result, the signal strength picked up by the antenna can vary over wide limits without affecting the output volume of the receiver. To show the advantage of this, assume the receiver is operating in a car and the car passes under a steel bridge. Provided the signal strength does not go below a certain small value, the volume output would remain the same, something that is not true of the usual a.m. receiver.

Another advantage resulting from the use of a limiter is that bursts of static trying to find their way through the already saturated limiter are practically wiped out. In other words, the limiter in an f.m. receiver performs the functions of the a.v.c. and automatic noise limiter circuits of an a.m. receiver, and performs them better.

Obviously, the limiter introduces tremendous distortion. In an a.m. receiver, this distortion would result in rather weird noises at the speaker. Since, however, it is variation in signal frequency rather than amplitude variation that counts in an f.m. receiver, this distortion has no ill effects. As a matter of fact, advantage is taken of an f.m. receiver's disregard of amplitude distortion by biasing the tubes so that maximum gain is obtained regardless of distortion. Thus, V_{102}, V_{103}, V_{104}, and V_{105} all have their cathodes connected to ground and are biased only by the small d.c. voltage drop across the grid resistor that results from cathode-to-grid current.

Audio System. From the limiter the signal passes on to the discriminator. A detailed technical description of the operation of this type of Foster-Seeley discriminator has been presented elsewhere, so let it suffice to say that here the frequency variations in the signal are transformed into an audio voltage corresponding to the original modulating signal at the transmitter. This audio voltage appears across R_{188} and R_{120} and is coupled through isolating resistor R_{152} to the volume control potentiometer R_{101} (through terminal 2 of jack J_{105} and terminal 2 of plug P_{105}). The ground return is completed through the number 1 pins of J_{105} and P_{105}.

From the volume control, the audio signal passes (via the number 6 pins on P_{105} and J_{105}) to a "de-emphasis" network composed of R_{149} and C_{149}. This attenuates the signal by an amount directly proportional to the frequency of the signal. This action, as you know, gives a "normal" audio signal from a phase-modulated carrier and at the same time reduces the high-frequency noise components in the discriminator output. If this de-emphasis network were not used, the output of the receiver would sound high-pitched and much noisier.

The audio signal next enters a filter composed of R_{150}, C_{135}, R_{119}, and C_{136}, a low-pass RC filter that further cuts down frequencies above 3,000 cycles. This is done because much noise, but little that adds to the intelligibility of speech, comes through above that frequency. The result of both these filter actions is a great reduction in noise output.

After coming from the filter, the audio is next applied to the pin 4 grid of the 7F7 audio amplifier (V_{110}), which amplifies it and passes it on to the grid of the 7C5 power output tube (V_{111}), from which up to 1.5 watts of output is obtained for driving the speaker.

Squelch Circuit. To understand the operation of the squelch circuit, let us first assume that no signal is being received by the set. Under this condition, the limiters are not saturated, and noise, which is not suppressed in the absence of a carrier, appears across R_{118} and R_{120} as an audio voltage. The higher-frequency components of this noise are used to operate the squelch system. The noise is coupled to the grid of the noise amplifier V_{108} through R_{129} and C_{159}. Output from the noise amplifier is taken from across L_{105} (which is tuned to approximately 15 kc. by C_{150}) by C_{134} and is rectified by the 7A6 half-wave voltage doubler (V_{109}). As a result of this rectification, a positive direct voltage appears at C_{155}. This voltage is filtered by R_{146} and C_{151} and applied to the pin 5 grid of V_{110}. Current is therefore allowed to flow through load resistor R_{137} and cause a large voltage drop across it. Since the pin 4 grid return of V_{110} is made through R_{122} to the negative side of R_{137}, the audio amplifier section of V_{110} is biased to beyond cut-off by this voltage drop across R_{137}, and the audio amplifier therefore ceases to function. As a result, all the noise that would otherwise appear in the speaker output when no signal is being received is automatically "squelched."

When a signal is received, the limiters become saturated and the noise reaching the discriminator and noise amplifier is greatly reduced. As a result, there is very little for squelch diode V_{109} to rectify, and the positive voltage on the pin 5 grid of V_{110} is greatly reduced. As a matter of fact, negative voltage (with respect to ground) from the first limiter grid through R_{144} and R_{131} is introduced into the squelch diode circuit in such a manner as to cause the pin 5 grid of V_{110} to go negative and provide cut-off. (This negative voltage from the limiter grid results from the cathode-to-grid current that flows when a signal is applied.) Since the d.c. amplifier section of V_{110} is now cut off, no d.c. voltage drop appears across R_{137} to bias the pin 4 grid to cut-off; hence, the receiver operates in a normal manner.

At first thought, you may believe that audio voltage from the transmitted signal may be amplified by the noise amplifier to operate the squelch circuit and cut off the audio amplifier. This does not happen, however; remember, the output circuit of the noise amplifier is tuned to 15 kc., and the 15-kc. components of the audio signal are greatly attenuated in both the transmitter and the receiver.

A squelch control is provided so

that the squelch circuit may be adjusted to allow the smallest possible signal above the noise level to operate the receiver. This control consists of a rheostat (R_{102}) which, through R_{125} and the number 2 pins of J_{105} and P_{105}, is in the cathode circuit of the noise amplifier. This control permits the gain of the noise amplifier to be varied by varying its bias.

An interesting feature of this squelch circuit is its action in eliminating the noise that would otherwise come through when the push-to-talk button is released after transmission. Ordinarily, the receiver would react to its associated transmitter the same as it would to any other carrier; that is, when the carrier disappeared, a short period would be required for the squelch circuit to go into action and turn off the audio amplifier. During this time, noise would be heard in the speaker. In this receiver, however, the squelch circuit is already in operation when the push-to-talk button is released, and, as a result, the noise crash does not come through.

SELECTIVE CALLING FOR POLICE SYSTEMS

Police radio systems, as well as many other mobile services, generally use a common carrier frequency for both the central station and mobile units. This means that all calls are received by each of the mobile units. Sometimes, especially in large cities, this will cause the mobile unit to be alerted by calls not intended for it. Selective calling will prevent this.

A selective calling arrangement for police systems does not have to be as elaborate as those used in marine and urban telephone services. In one system, single tones of 570 cycles are used. The stepping relay is a ten-point selector switch. When a mobile unit is called, the squelch circuit of the receiver is opened, thereby allowing the audio amplifier to operate, and a warning light is turned on. A warning bell or horn can also be turned on for a few seconds by the selective calling system if necessary.

A ten-point system is used because of its versatility. Each mobile unit is normally assigned a four-digit number whose sum is 10. There are 84 such combinations. A mobile unit whose number, for example, is 2-3-1-4 will have stops on the second, fifth, sixth, and tenth positions. When this number is dialed, the selector switches in all the units will operate, but only the one with the proper stops will advance to the tenth position and operate the warning signal. All others will return to normal position.

This system permits cars to be called individually or in groups. For example, the three-digit call 2-3-5 will cause not only 2-3-1-4 to respond but 2-3-2-3, 2-3-3-2, and 2-3-4-1 as well. A two-digit call, such as 2-8, will cause a larger group of cars to respond. There are a large number of group combinations available. When zero is dialed, 10 pulses are sent out and all cars will respond.

This flexibility makes selective calling a very desirable and useful feature. If more than 84 cars are used in the system, frequency-selective stepping relays and two or more dialing tones with different frequencies can be used.

Lesson Questions

Be sure to number your Answer Sheet 50RC-1.

Place your Student Number on every Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next Lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time or you may run out of Lessons before new ones can reach you.

1. Give two reasons why medium frequency police and fire communication systems are confined to one-way operation.
2. Even though the coverage is limited, why is the maximum value of r.f. carrier power used in mobile communication systems?
3. Why is the vertical quarter wave antenna widely used in v.h.f. mobile services in the 30-44 mc. band even though a horizontal antenna would give a better signal-to-noise ratio?
4. Why should the a.v.c. be fast in an a.m. receiver for mobile services?
5. Why is the usual police receiver permanently tuned to a fixed frequency?
6. Why is level-delayed a.v.c. used in a.m. receivers for mobile services?
7. What voltage in an a.m. receiver causes the squelch circuit to operate?
8. What is the basic principle of operation of the series type noise limiter of Fig. 6?
9. Why are carbon microphones used in mobile services?
10. What effect would you notice if you were listening to an f.m. service receiver, equipped with a squelch circuit, when a carrier came on?

GET ALONG WITH PEOPLE

In a recent study covering the activities of several hundred successful men, this question was asked:

"What single ability is most essential to success?"

The almost unanimous answer was:

THE ABILITY TO GET ALONG WITH PEOPLE.

You will agree with this, I am sure.

The successful technician — engineer — business-man — must *get along with* other people, if he is to gain the greatest success, and earn the greatest profit from his technical abilities.

Keep this in mind in your everyday life. *Practice getting along* with people. We can all improve on our abilities in this "art" — and will profit by doing so.

J. E. SMITH