U. S. Department of Justice
National Institute of Justice

National Institute of Justice
Technology Assessment Program

Personal Radio Guide

203-83

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About the Technology Assessment Program

The Technology Assessment Program is sponsored by the Office of Development, Testing, and Dissemination of the National Institute of Justice (NIJ), U.S. Department of Justice. The program responds to the mandate of the Justice System Improvement Act of 1979, which created NIJ and directed it to encourage research and development to improve the criminal justice system and to disseminate the results to Federal, State, and local agencies.

The Technology Assessment Program is an applied research effort that determines the technological needs of justice system agencies, sets minimum performance standards for specific devices, tests commercially available equipment against those standards, and disseminates the standards and the test results to criminal justice agencies nationwide and internationally.

The program operates through:

The *Technology Assessment Program Advisory Council* (TAPAC) consisting of nationally recognized criminal justice practitioners from Federal, State, and local agencies, which assesses technological needs and sets priorities for research programs and items to be evaluated and tested.

The *Law Enforcement Standards Laboratory* (LESL) at the National Bureau of Standards, which develops voluntary national performance standards for compliance testing to ensure that individual items of equipment are suitable for use by criminal justice agencies. The standards are based upon laboratory testing and evaluation of representative samples of each item of equipment to determine the key attributes, develop test methods, and establish minimum performance requirements for each essential attribute. In addition to the highly technical standards, LESL also produces user guides that explain in nontechnical terms the capabilities of available equipment.

The *Technology Assessment Program Information Center* (TAPIC) operated by the International Association of Chiefs of Police (IACP), which supervises a national compliance testing program conducted by independent agencies. The standards developed by LESL serve as performance benchmarks against which commercial equipment is measured. The facilities, personnel, and testing capabilities of the independent laboratories are evaluated by LESL prior to testing each item of equipment, and LESL helps the Information Center staff review and analyze data. Test results are published in Consumer Product Reports designed to help justice system procurement officials make informed purchasing decisions.

All publications issued by the National Institute of Justice, including those of the Technology Assessment Program, are available from the National Criminal Justice Reference Service (NCJRS), which serves as a central information and reference source for the Nation's criminal justice community. For further information, or to register with NCJRS, write to the National Institute of Justice, National Criminal Justice Reference Service, Washington, DC 20531.

James K. Stewart,
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National Institute of Justice

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National Institute of Justice

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Foreword

The Law Enforcement Standards Laboratory (LESL) of the National Bureau of Standards (NBS) furnishes technical support to the National Institute of Justice (NIJ) Technology Assessment Program to strengthen law enforcement and criminal justice in the United States. The overall NIJ Technology Assessment Program is briefly described on the inside front cover of this guide. LESL's function is to conduct research that will assist law enforcement and criminal justice agencies in the selection and procurement of quality equipment.

LESL is: (1) subjecting existing equipment to laboratory testing and evaluation and (2) conducting research leading to the development of several series of documents, including national voluntary equipment standards, user guides, and technical reports. The standards that are developed by LESL, following review by the Technology Assessment Program Advisory Council, are adopted by the International Association of Chiefs of Police (IACP) and recommended for use by its membership. These standards are also used by the IACP Technology Assessment Program Information Center (TAPIC) as the basis for testing commercial equipment, and the results of that testing are published in the TAPIC Consumer Product Information report series.

This document is a law enforcement technology guide developed by LESL under the sponsorship of NIJ. Additional guides as well as other documents are being issued under the LESL program in the areas of protective equipment, communications equipment, security systems, weapons, emergency equipment, investigative aids, vehicles, and clothing.

Technical comments and suggestions concerning this guide are invited from all interested parties. They may be addressed to the Law Enforcement Standards Laboratory, National Bureau of Standards, Washington, DC 20234.

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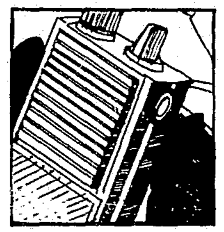
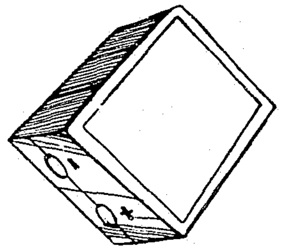
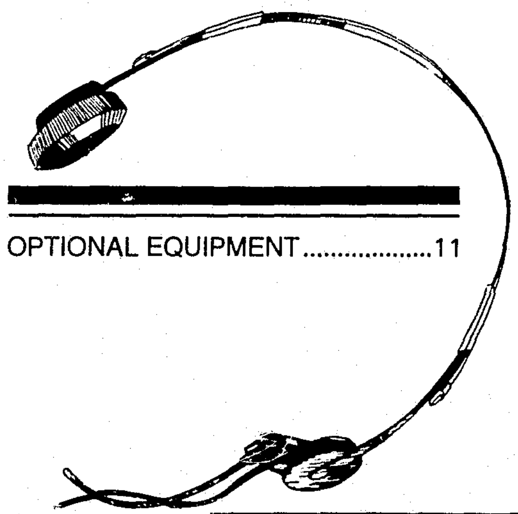






Introduction

The need for police officers to communicate with the radio dispatcher and other police personnel when not having access to a mobile radio has resulted in increased use of personal radios.[1] These lightweight radios can be carried at all times, whether the officer is on-duty or not, and they have become an effective tool of the law enforcement community.

This guide has been written for the benefit of law enforcement officials and others who are interested in the selection and use of communication equipment. It is one in a series of four guides. The other three cover mobile radios, base station equipment, and communication systems, respectively [1–3][2]. Persons desiring assistance in developing procurement specifications should consult the appropriate guide and the related performance standards. These publications have been developed for a wide variety of communication equipment. Although tailored specifically for law enforcement application, they are also suitable for other public-safety and land-mobile use. They are listed in table 1, grouped by subject area. In addition to those listed in the table, standards are now being developed for mobile digital equipment, microphone cable and connectors, control heads, microphones, logging devices, and selective signaling equipment.

TABLE 1. USE OF DOCUMENTS

Application	Applicable documents
Communication system planning	NBS Special Publication 480-12, Communication Systems Guide Any or all of the others listed in this table
Mobile transceiver procurement	NILECJ-STD-0202.00, Mobile FM Transmitters NILECJ-STD-0205.00, Mobile Antennas NILECJ-STD-0207.00, Mobile FM Receivers NILECJ-STD-0212.00, RF Coaxial Cable Assemblies for Mobile Transceivers Mobile Radio Guide
Personal/portable transceiver procurement	NILECJ-STD-0209.00, Personal FM Transceivers NILECJ-STD-0211.00, Batteries for Personal/Portable Transceivers Personal Radio Guide Police Personal FM Transceivers Report
Base station equipment procurement	NILECJ-STD-0201.00, Fixed and Base Station FM Transmitters NIJ Standard-0204.01, Fixed and Base Station Antennas NILECJ-STD-0206.00, Fixed and Base Station FM Receivers Base Station Equipment Guide
Accessory equipment procurement	NBS Special Publication 480-8, Voice Scrambler Guide Guides for: Mobile Radios, Personal Radios, Base Station Equipment (In preparation); and Communication Systems (NBS Special Publication 480-12) LESP-RPT-0207.00, Electronic Eavesdropping Techniques and Equipment

[1] Although they are really transceivers, i.e., having the capability of both transmitting and receiving messages, the devices are commonly called radios.

[2] Numbers in brackets refer to the references in appendix A.

The purpose of this guide is to provide general background information which will help law enforcement agencies analyze their personal radio needs and select the best equipment to meet these needs. It describes some of the characteristics of personal radios that are currently available, and discusses most of their applications in law enforcement communication. The information in this guide will also be useful when discussing personal radio requirements with manufacturers and communication experts.

The items discussed in this guide include the use, construction, maintenance, and cost of radios; batteries and battery chargers for radios; antennas, equipment options, and operational considerations.

A report of tests conducted on police personal FM transceivers [4] by the International Association of Chiefs of Police should assist individuals who are interested in personal radio performance. That report presents the results of tests of commonly used personal radios, when tested using the National Institute of Justice standard [5].

Personal Radio Equipment

Personal radios are small, portable transceivers intended to be handcarried or attached to the clothing of the user. These units consist of a frequency-modulated (FM) transmitter and receiver, an antenna, and a power source. Personal radios used by the law enforcement community are available in the 25–50 MHz (VHF low-band), 150–174 MHz (VHF high-band), 400–512 MHz (UHF band), and 806-896 MHz (UHF band) frequency bands. They are also available with many options which will be discussed later.

DESIGN AND CONSTRUCTION

Manufacturers have designed personal radios using several packaging concepts. One concept utilizes a detachable battery package that is an extension of the shape of the radio. The connection that joins the battery package to the radio performs two basic functions. It provides an electrical connection for quick replacement of the battery package, and also provides a mechanism for locking the battery package to the radio. The detachable battery package permits interchangeability of batteries between like units and the use of the radio with a variety of batteries depending on the capacity required.

Another concept uses a removable cover to a battery compartment at the base or back of the radio without destroying the integrity of the electronic compartment waterproof seal.

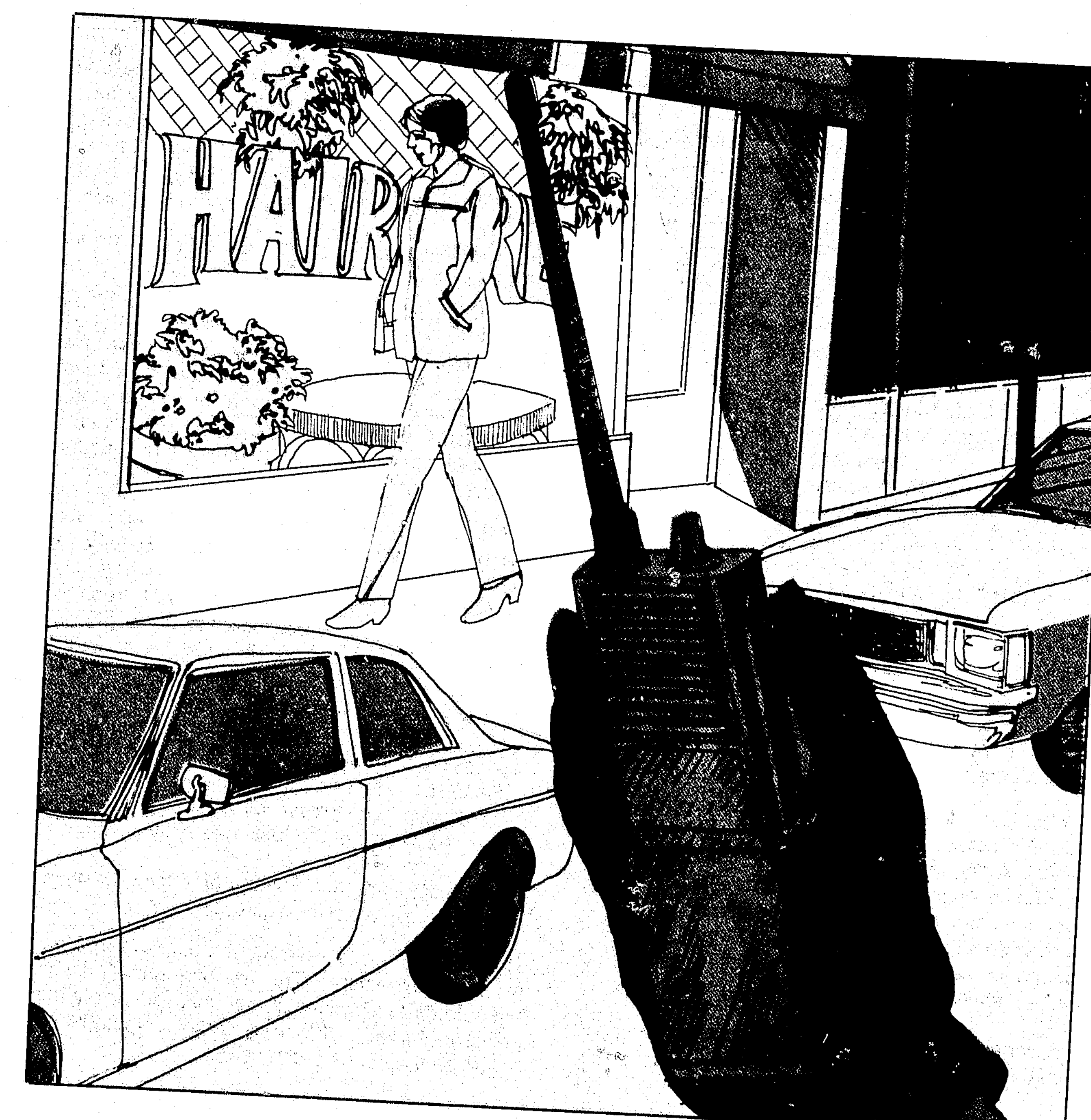
The performance of the personal radio antenna is influenced by the size, shape, and material used in the personal radio case. Either metallic or metal-plated plastic cases usually provide improved antenna performance.

Some older personal radios primarily used discrete components; however, as a result of continuing improvement in technology and fabrication techniques, several generations of improved personal transceivers have evolved. With the advent of monolithic and hybrid integrated circuits, complete oscillator subassemblies, including oscillator and multiplier circuits, have been built into small plug-in modules. These plug-in modules improve the field serviceability of personal radios. Some modules are enclosed in metallic housings. The metallic housing provides some shielding, which usually improves the intermodulation performance of the receiver. A supply of spare modules can be accumulated to expedite repairs of the transceivers; however, repair of a module itself is usually difficult.

An important feature to the user is the "feel" of the switch detent action of the off-on and frequency selection switches. Frequency selection must sometimes be made in the dark or in poorly lighted locations. The required channel is often remembered as a certain "click" or detented position from the stop position. It is desirable to be able to select this detented position with a gloved hand. The detent action of the off-on switch, which in many units operates in conjunction with the volume control knob, should be stiff enough to avoid accidentally shutting the unit off, thereby preventing the officer from missing any messages.

COST

Personal transceiver units that are compatible with existing law enforcement communications systems are available for as little as $600. Like any product, as options are added (such as multifrequency capability, continuous tone-coded squelch, nickel-cadmium rechargeable batteries, and increased battery capacity) the cost increases. Units equipped with all of the options may cost as much as $2000 for a single radio with accessories. This cost can usually be reduced substantially by buying in quantity, using competitive bidding procedures.



Batteries

DESCRIPTION OF TYPES

A battery is the power source of almost all personal radios. Batteries are available in an assortment of voltages, capacities, sizes, and weights; however, there are only two basic types. These are primary or throwaway batteries and secondary or rechargeable batteries. The primary battery is constructed so that only one continuous or intermittent discharge can be obtained. After the battery is discharged, it should be discarded and a new battery installed. The use of primary batteries is limited in law enforcement work even though they are available for most personal transceivers. The most common primary batteries on the market are the carbon-zinc, alkaline, and mercury types. The carbon-zinc and alkaline batteries have a nominal output of 1.5 V per cell. Alkaline primary batteries are best suited for high current drain applications and usually last twice as long as the carbon-zinc batteries. The mercury battery has a nominal output of 1.4 V and is known for its flat voltage discharge characteristics. Its high-energy density and long shelf life make it desirable for use in personal radios. Care should be taken not to burn discarded mercury batteries because they emit poisonous fumes.

If a primary battery is being used to power a personal radio, it is advisable to carry a spare battery. A dry battery stored on the shelf tends to lose some of its capacity over a period of time. The shelf life of each battery depends on the storage conditions and the type of battery. Of the commonly used batteries, carbon-zinc has the shortest shelf life and mercury has the longest.

A secondary battery can be recharged following a partial or complete discharge. Secondary batteries fall into two general classifications: alkaline and acid. Alkaline secondary battery types include nickel-cadmium, silver-zinc, and nickel-iron batteries; however only nickel-cadmium batteries are presently commercially available in large quantities, and are the only ones discussed in this guide.

The lead-acid battery is best known for its use in automobiles. It can supply large currents at a relatively high output of slightly more than 2.0 V per cell. The size and weight of the lead-acid battery has in the past restricted its use for personal transceivers. However, recent advances have resulted in the development of sealed lead-acid batteries that are rechargeable, spill resistant, and can be packaged in a size and weight suitable for personal radio use.

The most common secondary battery used for personal radios is the nickel-cadmium battery. It has a nominal output of 1.35 V per cell when fully charged. When placed in use, this output drops to an average of 1.2 V per cell for most of the discharge time. This ability to produce a stable voltage during use, plus its other characteristics, make it a good choice for personal radios. Additional battery performance characteristics are discussed in reference [6]. The Technology Assessment Program Information Center has begun testing batteries for personal radios and will publish the results of the testing at a later date.

Figure 1 compares the voltage of various types of cells during typical discharge cycles.

The selection of batteries by the user is simplified by the manufacturer. The manufacturer lists the possible battery options, if any, that will supply the power to the radio. If there is a choice it should be based on the needs of the user.

CHARGERS AND CHARGING TECHNIQUES

As discussed in reference [7], proper charging techniques are important to secondary batteries in order to obtain maximum battery life. Each type of secondary battery has its own charging peculiarities.

Charging techniques directly affect the useful life of a nickel-cadmium battery. A high charging current (in the range of several amperes) may not do any harm during the first 85 percent of the charging cycle, but it may cause overheating or venting, resulting in probable damage to the battery, if the charging current is not decreased rapidly during the last 15 percent. The 85 percent charged condition is usually detected by a thermal sensor. To eliminate this problem, many manufacturers recommend the use of a constant current charger that utilizes smaller charging current and requires from 14 to 16 h to completely recharge the battery.

System effectiveness can be increased by the use of a short or rapid charging cycle for the nickel-cadmium battery. The number of standby or reserve batteries can be minimized if such a system is used. Batteries and chargers designed for rapid-charge have built-in sensing circuitry to limit the charge current when the battery approaches full charge conditions. Field experience indicates that repeated rapid-charge of batteries does not damage the battery. However, a rapid-charge system can cost four times the price of the slow-charge system. The charging rate of the rapid-charge system is typically 10 to 20 times faster than a slow-charge rate.

The battery duty cycle of a personal radio, such as 10 percent transmit, 10 percent receive, and 80 percent standby (10–10–80), is an often discussed term. A frequent criticism is that the duty cycles specified in test procedures do not represent actual field usage. Nearly every user has an estimate of the representative percentages of the duty cycle for shifts in his or her department.

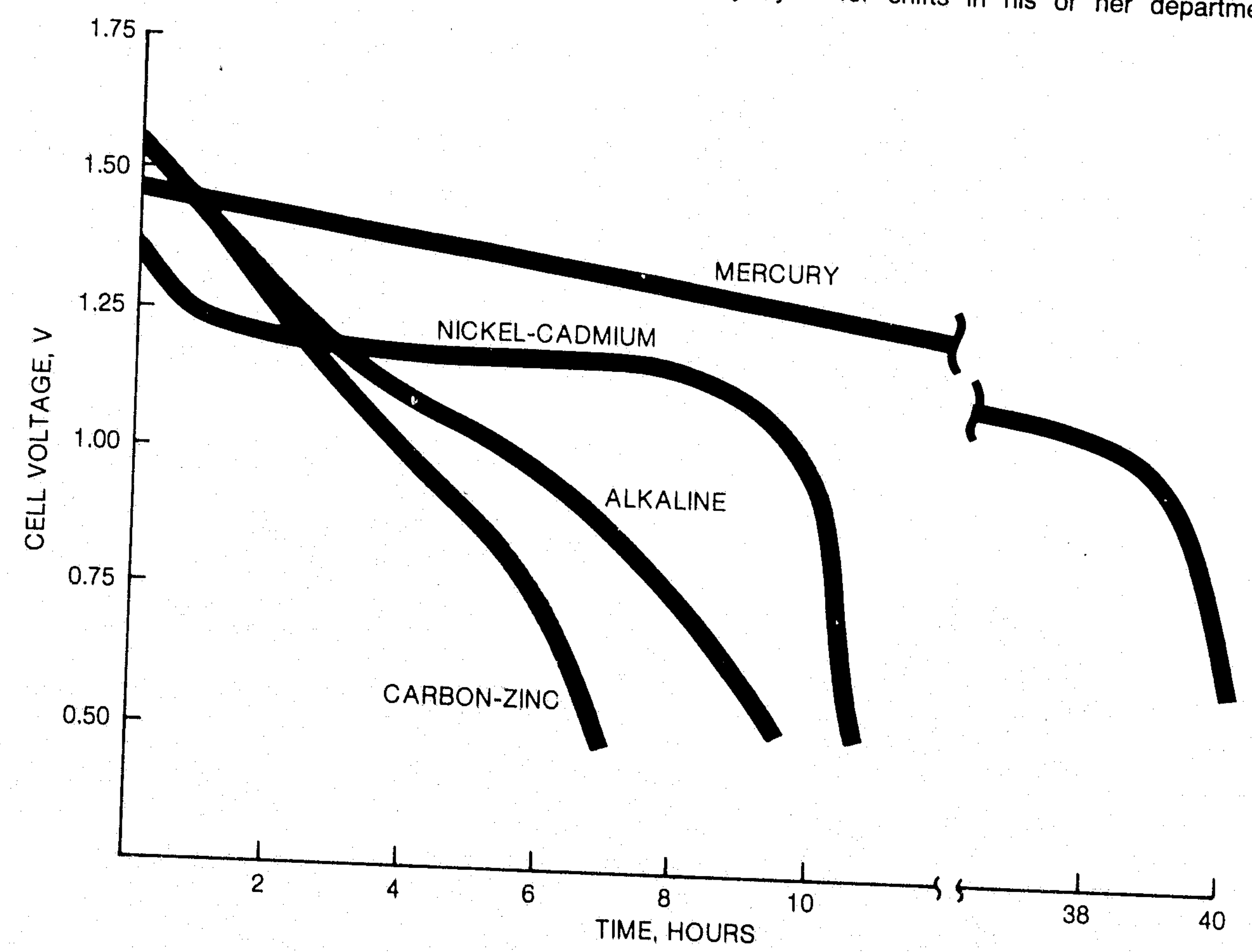
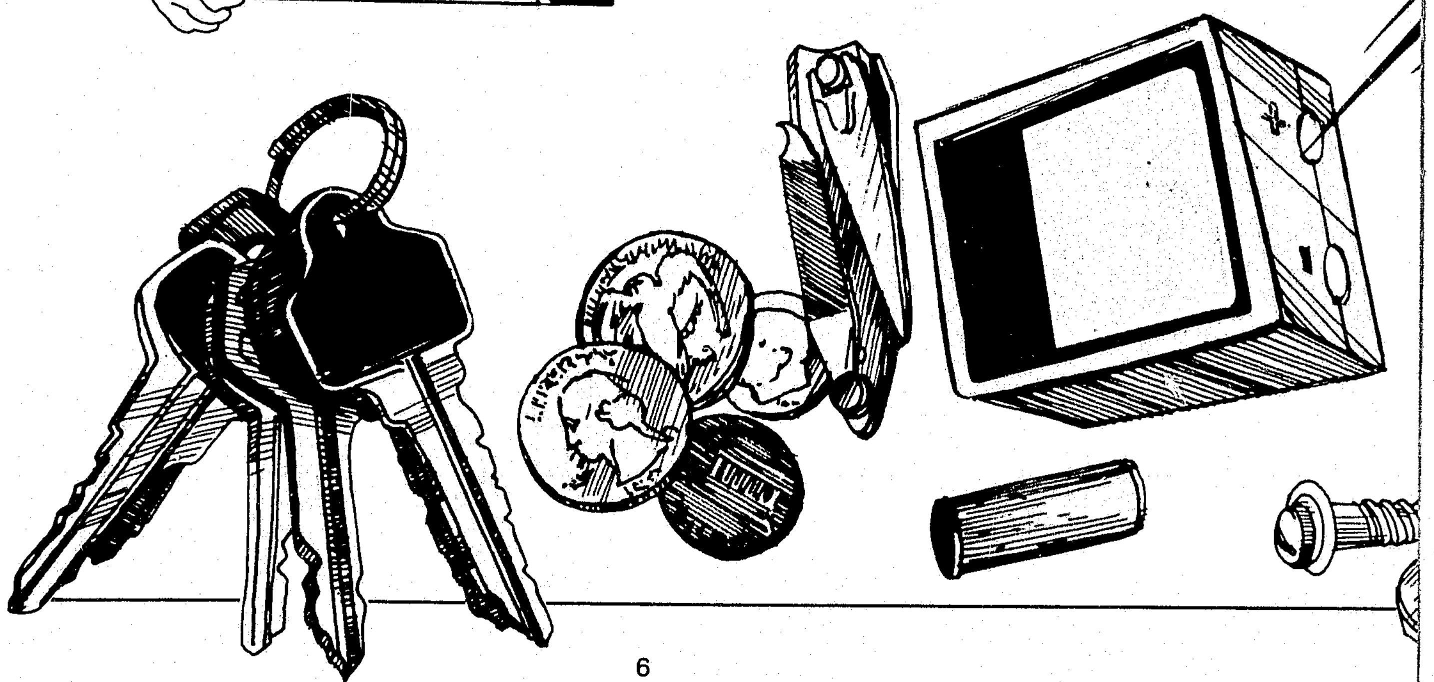


Figure 1. Typical cell voltages during discharge.

However, it should be kept in mind that the standard duty cycle provides a uniform criterion to compare the performance of all batteries used with a specified transceiver. If use in the field is greater than 10 percent in the transmit mode, the service life of the battery will be shortened. NILECJ-STD-0209.00 [5] defines the service life of a battery in a given transceiver as the length of time that a battery-powered radio will produce one-half of the rated output power or more during a 10–10–80 percent duty cycle.

Nickel-cadmium batteries have unique characteristics. Storage in a cool, dry environment promotes longer battery life, while operation at high temperatures increases service life. Batteries may be stored in either the charged or discharged condition, but they tend to lose their charge when stored for long periods of time. A battery can be safely charged after being in a cold environment if it is allowed to warm to room temperature before



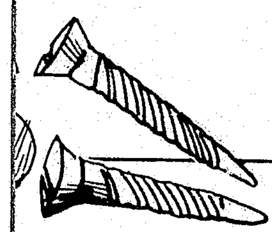
charging, but operation in a cold environment reduces its available capacity. Nickel-cadmium batteries have the ability to deliver extremely high currents in a short time period when they are accidentally short circuited. If a nickel-cadmium battery or a personal radio/battery combination is inadvertently placed in an officer's pocket with metallic objects such as keys and coins, the contacts can be shorted and excessive localized heating can result. A serious burn is possible, and under certain conditions of high current discharge, a battery explosion could occur. On at least two occasions, placing a radio/battery combination in the same pocket with several cartridges resulted in the accidental discharge of one of the cartridges. The use of a carrying case is recommended to avoid shorting the battery. The battery life of a nickel-cadmium battery can be expected to range from 400 to 1000 charge-discharge cycles.

CAPACITY

The efficiency of the transmitter portion of a personal radio is a measure of how well the equipment uses its available battery capacity to generate radio frequency energy. Efficiencies of typical equipment range from 40 to 60 percent when comparing the dc power input to the radio with the rf power delivered to an output load. Manufacturers often describe tuning procedures that optimize transmitter current drain when the radio frequency power is delivered to a standard output load.

The upper limit of the capacity of most nickel-cadmium batteries used in personal radios is approximately 1 A-h. A typical 2-W radio with a current drain of 0.75 A while transmitting will have a current drain of approximately 0.075 A while receiving, and approximately 0.005 A during standby. When operated during an 8-h shift at a typical 10–10–80 percent duty cycle, such a radio would use 0.692 A-h, or less than 70 percent of the available battery capacity.

Personal radios that employ frequency synthesis techniques, rather than crystal-controlled elements, for the determination of their operating frequencies have higher standby current drains than radios using fixed-frequency crystals. These current drains are typically 5 to 10 times higher than normal standby currents, i.e., from 0.025 to 0.05 A, rather than the 0.005 A used in the previous example.



Antennas

ANTENNA PERFORMANCE

Most antennas available for use with personal radios are low gain or lossy antennas when compared with a half-wavelength dipole antenna. Typical antenna losses, measured in decibels below a half-wavelength dipole (dBd), of two commonly used antenna types are listed in table 2.

When operated at face level, the quarter wavelength telescoping antenna is less lossy than the helical spring antenna. However, if the quarter wavelength antenna is collapsed and worn at belt level, the helical spring antenna outperforms it at VHF frequencies. This change in performance would be most noticeable when receiving. When transmitting using a telescoping antenna, the personal radio is normally removed from the belt and used at face level with the antenna extended. Careful analysis of the use and application of the personal radio is essential before selecting an antenna.

When planning a system where officers are wearing personal equipment on their belts, recall that telescoping antennas in the collapsed condition will require a larger received signal than helical spring antennas. If helical spring antennas are used, the transmit efficiency is reduced, and the receiving station (usually a base station) may require additional receiving capability in the form of improved antenna gain, additional receivers and/or a preamplifier in the base station receiver.

TABLE 2. TYPICAL ANTENNA LOSS

	Antenna loss (dBd)	
Antenna type	VHF	UHF
One-quarter wavelength telescoping (extended and held at face level)	5	20
One-quarter wavelength telescoping (collapsed and worn at belt level)	45	50
Helical spring (held at face level)	10	25
Helical spring (worn at belt level)	25	50

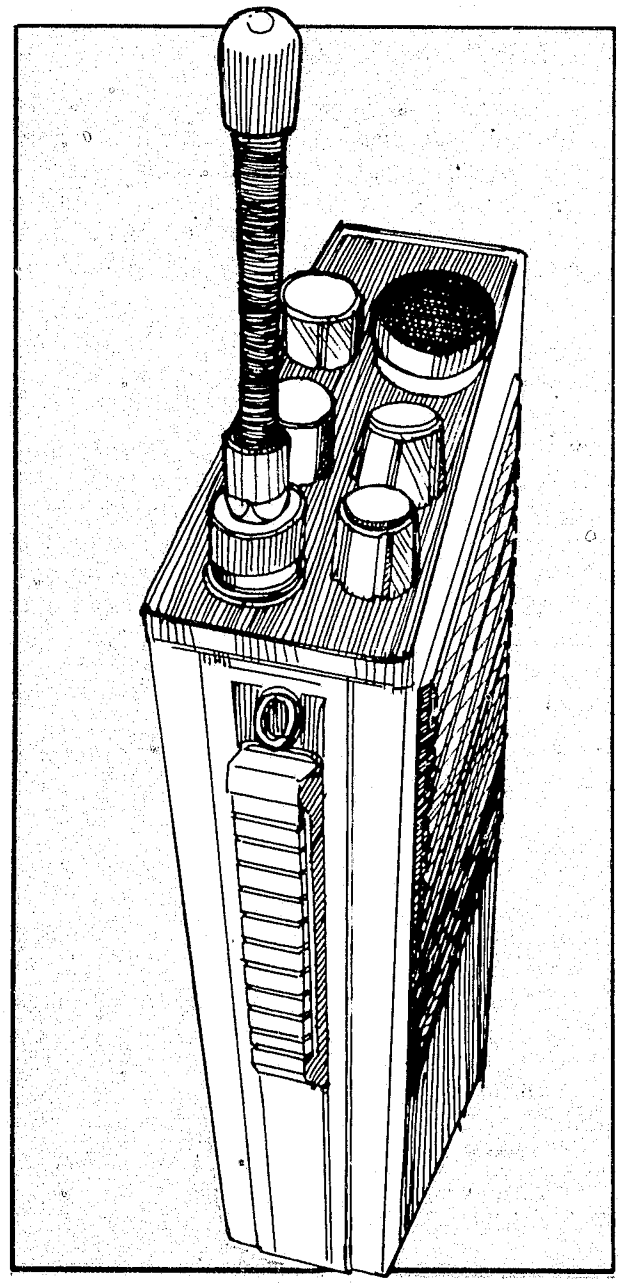
ANTENNA CONSTRUCTION

Physical antenna length is a compromise between optimum size and convenience, especially in the 50 and 150 MHz regions. The awkwardness of a 50 MHz personal antenna makes operation in this frequency band inconvenient unless the antenna is shortened. Reduction in physical length, however, reduces the effectiveness of the antenna.

In the 150 MHz region, the most effective radiator is a quarter-wavelength noncollapsible rod antenna. The rod antenna is not as convenient as a collapsible tubular antenna that stores within the personal transceiver. Most users find that extending the antenna is troublesome. Deterioration of the slide contacts within the tubular sections make this antenna subject to intermittent contact after many pull-up cycles. A compromise antenna of limited physical length is the helical spring antenna. It is flexible, quite durable, and is approximately one-third the length of the pull-up antennas.

Helical antennas are also used in the 450 MHz band. However, as shown earlier, this type of antenna is not as efficient at 450 MHz as at 150 MHz. Personal radio antennas at 450 MHz are usually a quarter-wavelength long and are of the pull-up or flexible shaft construction.

In addition, the radiation efficiency of typical personal radio antennas can be expected to be from 10 to 50 percent. Radiation efficiency is defined as the ratio of the effective radiated power of a transmitter-antenna system to the transmitter power output into a 50-ohm load. Selection of personal radio antennas should be based on the required efficiencies and the use of the antenna. If, for example, a helical spring antenna is used, the additional transmission loss due to the less effective antenna may have to be made up in other parts of the communication system in order to maintain the same level of performance. This could be achieved by using an improved base station antenna or an additional remote station receiver. The efficiencies of the transmitter and the antenna are both critical to overall performance of personal radios.

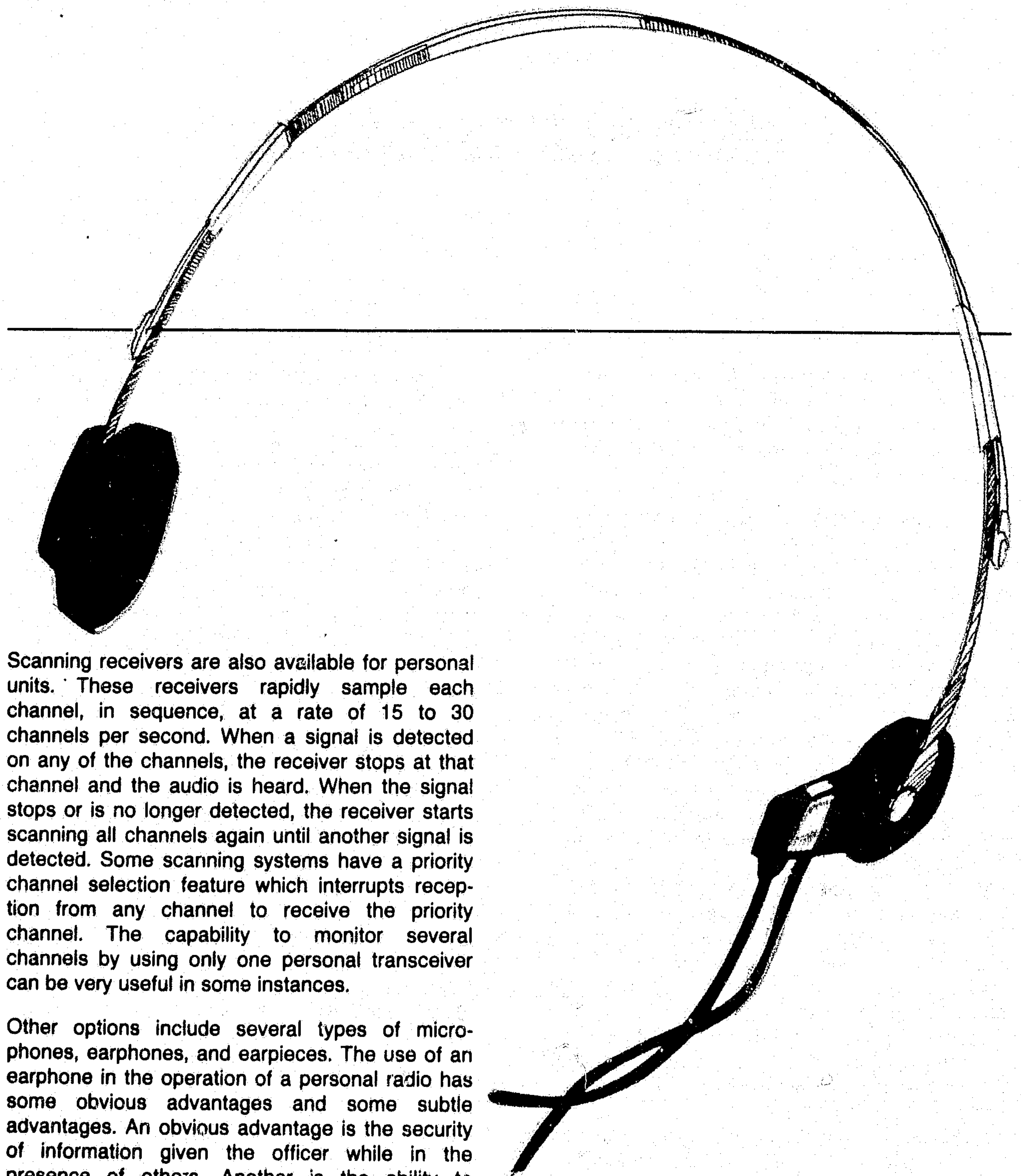


Optional Equipment

Many options are available for personal radios. Because these options not only increase complexity and weight but significantly influence the cost of each unit, the buyer must carefully consider user needs before selecting any of them.

Equipment is available that can operate on many frequencies for both the transmitter and receiver. When selecting radios, the user should determine whether or not the assigned operating frequencies are within the maximum frequency separation specified by the radio manufacturer. Frequency separation in a given band is defined as the difference between the maximum and minimum frequency at which the radio can transmit or receive and still perform in accordance with manufacturer's specifications. Attempts to operate the radio with a frequency separation that exceeds that specified by the manufacturer will most likely degrade the performance of the transmitter and/or the receiver. The majority of personal radios will only perform satisfactorily over a range of ±0.5 MHz from the center of the operating band, a total frequency separation of about 1 MHz. For example, frequencies are assigned to law enforcement agencies in both the 154 and 159 MHz bands. Obviously, when the operating frequencies of a police department are all within a 1-MHz band centered on either 154 or 159 MHz, there is no problem. If a department has been assigned transmitting or receiving frequencies in both the 154 and 159 or Hz bands, the frequency separation could be almost 6 MHz, and the majority of personal radios would not perform satisfactorily in both frequency bands. However, some radios now being sold are equipped with dual front ends, i.e., two or more separate rf sections utilized so that a greater frequency separation can be achieved. For example, one rf section may operate in the 154 MHz range and the second may operate in the 159 MHz range, thus achieving a much greater overall frequency separation.

Selective calling systems are available as options for most personal radios. Several techniques are used. One popular technique called Continuous Tone-Coded Squelch Systems (CTCSS) uses selected sub-audible tones to open the squelch circuit. Other techniques make use of audible tones for burst and sequential tone coding. Some manufacturers also offer digital coding techniques to provide selective calling. CTCSS is the most commonly used tone coding technique, but the number of private codes are limited. The use of digital techniques, on the other hand, allows the use of many more codes. A performance standard for use in selecting a typical squelch system has been developed [8] and a second one is in preliminary draft form [9]. In some cases, personal radios can be retrofitted for selective calling. However, some units do not have the additional space needed to accommodate selective calling modules. Therefore, if adding some type of selective calling at a later date is contemplated, organizations should make certain that the housing of the personal radio purchased is of adequate size to house the future add-on modules.



Scanning receivers are also available for personal units. These receivers rapidly sample each channel, in sequence, at a rate of 15 to 30 channels per second. When a signal is detected on any of the channels, the receiver stops at that channel and the audio is heard. When the signal stops or is no longer detected, the receiver starts scanning all channels again until another signal is detected. Some scanning systems have a priority channel selection feature which interrupts reception from any channel to receive the priority channel. The capability to monitor several channels by using only one personal transceiver can be very useful in some instances.

Other options include several types of microphones, earphones, and earpieces. The use of an earphone in the operation of a personal radio has some obvious advantages and some subtle advantages. An obvious advantage is the security of information given the officer while in the presence of others. Another is the ability to maintain silence during an investigation. Additionally, if an earphone is used in the personal radio, and the officer uses the vehicle transmitter, the acoustical feedback in the personal radio is eliminated. Personal radios that are belt worn or placed on the vehicle seat can be a source of acoustical feedback unless an earphone is used.

Operational Considerations

The complete design of a communication system is beyond the scope of this guide; however, a few important points will be discussed that are pertinent to day-to-day use of personal radios. See references [1-3] for additional information regarding mobile radio systems.

PROPAGATION AND BUILDING PENETRATION

Propagation of radio signals and probability of radio coverage go hand-in-hand when planning or estimating system performance. Service areas covered and the quality of service required are two valid measures of performance. A system that must provide almost 100 percent coverage for almost 100 percent of the time requires considerable redundancy and overdesign.

Propagation into and out of buildings is often required when using handheld equipment. Measurements indicate that the lower frequencies (50 MHz) are attenuated more by buildings than are the higher frequencies (150 MHz and 450 MHz). Typically, the average building losses at low band (50 MHz) are approximately 25 dB, while losses at high band (150 MHz) are approximately 20 dB. The ultrahigh frequencies (450 MHz) are attenuated less than the lower frequencies because their shorter wavelengths are more nearly equal to typical window sizes and other structural apertures used in buildings.

In the typical situation the receiving range of the personal radio exceeds the transmitting range. Most personal radios have receiver sensitivities that are adequate to receive transmissions from the base station. However, because of their lossy antennas and low-power output, they often have difficulty transmitting a usable signal to the base station.

AVAILABILITY AND CHOICE OF FREQUENCIES

The selection of a frequency or frequencies can be a difficult problem with today's crowded frequency spectrum. Assistance in the choice and availability of frequencies is provided by an Associated Public-Safety Communications Officers, Inc. (APCO) frequency coordinator who recommends which available frequency the applicant should request for licensing by the Federal Communications Commission (FCC). The FCC itself coordinates frequency assignments in the newly opened 806-896 MHz band. The FCC states in its rules and regulations that each police entity is entitled to at least one police frequency. If many small jurisdictions exist in close proximity, each will be assigned its own frequency. Although this creates crowding of the spectrum, it may be tolerable if the usage per channel is minimal. In many areas, centralized facilities have relieved this situation. The concept of regional communication centers has developed where several jurisdictions have combined their communication operations and reduced their need for separate frequencies. The overall goal is to efficiently and effectively utilize the radio spectrum.

The availability of frequencies and the geographic terrain must be given proper weighting when a communication system is planned. Systems in metropolitan areas that are heavily populated with high-rise buildings can usually operate effectively in the 450 MHz band. Rural areas covering large geographic jurisdictions may be served best by the frequencies in the 150 MHz region. Man-made noise is prevalent in the metropolitan environment. Man-made noise attenuates rapidly with increasing frequency; therefore, the higher frequencies are less likely to encounter such interference than are the lower frequencies.

SYSTEM IMPROVEMENTS

A voting receiver system, one with several satellite receivers coupled to a comparator to select the one receiving the best signal, will improve the performance of personal radios in areas where existing coverage is marginal. Urban areas, shopping centers, or large warehouse complexes

can be better protected if personal radio coverage is improved by the use of such a system. Systems have been successfully installed such that, when the dispatcher receives a message from a personal radio via a specific voted receiver at the base station, the reply by the dispatcher is returned by a remote transmitter located near the personal radio user. This approach will readily provide reliable coverage to the geographic area from which the original message was transmitted by the personal radio. This method is frequently called a voted base station.

A variation of this concept is the mobile-mobile repeater. If an area has adequate coverage using 30- to 100-W mobile radios, a mobile-mobile repeater can be a valuable addition. Many emergency situations require an officer to leave the vehicle. Officers who carry a personal radio that can change the mobile radio into a repeater are better equipped to perform their duties safely. By having the ability to control the mobile repeater from the handheld unit, usually by means of tone control, the officer has no need to change the mobile unit to a repeater before leaving the vehicle, but may do so at any time.

USE

Heavy winter clothing will reduce the effective radiated power of a radio worn under a coat. An extension or remote speaker/microphone is very useful in cold weather climates, as this type of microphone can be clipped on the lapel of a heavy uniform coat. In addition, nylon hook and pile material has been successfully used to secure the remote speaker/microphone to an officer's uniform. The pile material is usually placed on the officer's uniform, such as the epaulet, and the hook material is fastened to the speaker-microphone.

Belt-worn radios usually are not dropped as often as handheld radios. However, the effective radiated power of the belt-worn device may be significantly reduced because it is absorbed by the user's body. This reduction, plus the losses incurred by the helical spring antenna when used in the belt-worn position, accounts for the degradation in performance of the belt-worn radios.

Because of the low output power of personal radios, many users find that removing the unit from the belt and pulling up a collapsible antenna to obtain a more reliable transmitted signal is only a small inconvenience. However, this additional handling also increases the likelihood that the transceiver may be dropped and damaged.

SAFETY

The Williams-Steiger Occupational Safety and Health Act of 1970 brings the force of law to many areas involving safety for employees. In law enforcement communications, one area of particular interest to operators and repair technicians of base station, mobile, and personal/portable transmitting equipment is that of non-ionizing radiation. Section 1910.97 of OSHA's Occupational Safety and Health Standards specifies radiofrequency radiation levels which should not be exceeded. The Radiation Protection Guide (RPG), contained in OSHA's standards, limits the maximum exposure to either a power density of 10 mW/cm^2 (equivalent to a field strength of 194 V/m) averaged over any possible 0.1-h minimum period, or an energy density of 1 mW-h/cm^2 (equivalent to a field strength of 61.4 V/m) during any 0.1-h period. The RPG which applies to incident electromagnetic fields at frequencies between 10 MHz and 100 GHz also is applicable whether the radiation is continuous or intermittent. The RPG is customarily interpreted as follows:

> A worker can be exposed to a radiation level of 10 mW/cm^2 (194 V/m) for 0.1 h or more per hour and not exceed the RPG limit. If he or she were to be exposed to a radiation level of 100 mW/cm^2 (614 V/m) for 0.01 h (36 s) every 6 min, the RPG limit still would not be exceeded. The RPG limit would be exceeded, however, if the worker were exposed to this level for longer than 0.01 h, or more than once every 6 min.

The RPG applies both to whole body and partial body irradiation. The critical parts of the body are the eyes and genitals, and medical evidence indicates that the biological effects can be additive for repeated exposures.

Although personal radios are low-power devices, usually rated at 1 to 5 W, high-level field strengths can exist in very close proximity to the transmitting antenna. Both theoretical calculations and measurements made at the National Bureau of Standards show that field strengths of approximately 200 V/m exist within 1 or 2 cm of the antenna of some personal radios. Because of the close proximity of the head and eyes to the personal radio during operation of the transmitter, one should be aware of the existence of these high-level fields.

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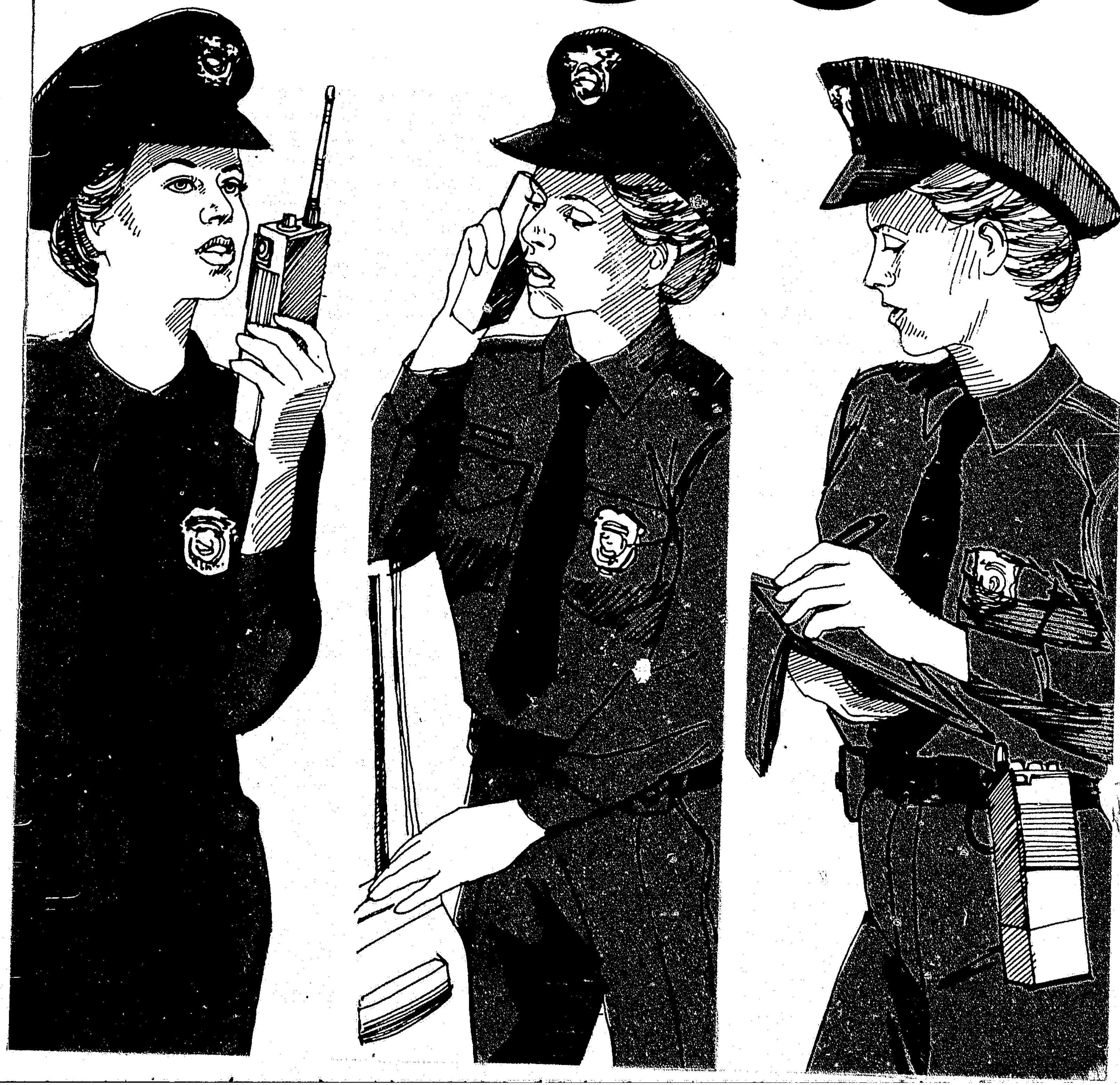

Maintenance

Maintenance should be a major consideration when purchasing a personal radio system. Personal radios, being small, are susceptible to being dropped, having antennas broken, and other misuse. Agencies should decide whether it is more practical and economical to perform their own maintenance or contract it to outside repair facilities. Some manufacturers offer worthwhile training courses for technicians.

Maintenance of personal radios can be simplified by using the specialized test fixtures recommended by each manufacturer. Personal radios have test point markings on the printed circuitry, as well as a metering socket used in adjustment of the equipment. Care in servicing personal equipment is extremely important, because a slip of a test probe on the closely spaced conductors of printed circuit boards can result in damage requiring hours to repair.

Recent Improvements

Automated test equipment has been developed that allows a series of transmitter and receiver measurements to be made in a short time interval. With computer-aided test facilities of this type, personal radio performance may be measured readily upon purchase and monitored on a periodic maintenance schedule rather than on a "fix it when it fails" routine. Presently, automated test equipment costs are high, but rapid advancements in microprocessor technology will undoubtedly reduce the future costs of such systems.

Another area of advanced design in personal radios is the automatically-controlled reduction of the output power of personal transmitters from the base station. Once the base station establishes the rf amplitude of the signal received from the personal radio, the base station transmitter telemeters the proper rf output power level required by the personal transmitter to satisfactorily continue the contact and conserve battery capacity of the personal radio.

The personal radio, in many special applications, is being equipped with 12-button telephone signaling switches. The effectiveness of this version for command and control of repeating equipment has been demonstrated in existing communication systems. As confidence is gained in the appropriate use of this equipment and suitable interlocks are used to prohibit access by unauthorized personnel, the personal radio with telephone access will permit the police officer to call any telephone number.

Appendix A—References

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