IMTS - IMPROVED MOBILE TELEPHONE SYSTEM

Contents

1. GENERAL

1.1 This section is intended to provide REA borrowers, consulting engineers, and other interested parties, with information on the operation of IMTS (Improved Mobile Telephone System) and its application to telephone service.

1.2 For detailed information, engineering considerations, cost studies, etc., refer to REA TE & CM-940, "Use of Mobile and Fixed Radiotelephone for Subscriber Service and for Operation and Maintenance."

2. MOBILE TELEPHONE SYSTEMS

2.1 Telephone service has been provided to subscribers in automobiles since the mid 1940's. The first systems were manually operated much like the early land line systems that depended on an operator to make the connection and signal the called party. Manual mobile units do not have supervisory signaling or dialing capability with the exception of the "off-hook" signal, which is produced by transmitting an unmodulated carrier.

2.2 Dial telephone service has been provided to subscribers in automobiles since the middle 1950's. This made it possible for small telephone companies without operators to provide mobile telephone service.

2.3 A problem with the early dial systems was the incompatibility caused by the different types of signaling used in the different types of systems. This was necessary to gain experience with a variety of signaling methods; however, it was a deterrent to the development of a nationwide mobile telephone system. Another undesirable feature was the push-to-talk operation required of the mobile subscriber.

3. IMTS - PRINCIPLES OF OPERATION

3.1 IMTS offers several outstanding features which include the following:

3.11 Full-duplex operation without using the push-to-talk button.

3.12 Better transmission resulting from a new generation of radio equipment designed to meet modern telephone standards.

3.13 Practically no loss of time to the radio channel on a land line to mobile call when the mobile equipment does not acknowledge; hence, improved traffic handling capability.

3.14 Capability of expansion to multichannel operation with the accompanying increase in traffic-handling ability through automatic channel hunting.

3.15 Two kinds of signaling, manual and IMTS, which are compatible with all other manual and IMTS systems. This permits more roamers to be served and delays obsolesence of equipment.

3.16 A unique numbering system which conforms to the nationwide plan and offers distinctive mobile numbers regardless of where a mobile subscriber may roam.

3.2 The features mentioned above are described more fully here:

3.21 Duplex transmission implies that either party may interrupt the other while he is talking. This was only half true in the early systems. The mobile subscriber could interrupt the land subscriber, but the mobile subscriber could not be interrupted because he was operating on a push-to-talk basis. He could not hear the other party while he was talking. However, some mobile units, prior to IMTS, offered duplex transmission when the push-to-talk button was depressed. IMTS mobile units are duplex telephones like any land telephone except for revertive calls in a single channel system.

3.22 Mobile Radio equipment has always, by design, had poor audio quality. The high frequencies were purposely "rolled off". IMTS radio equipment has a wider voice frequency bandwidth which approaches that of modern land telephone systems.

3.23 In the past it was understood that the channel would be busy during the entire signaling time even if the mobile subscriber did not answer. IMTS mobiles are signaled only once to determine if they are in a position to communicate before the "ringing" begins. Hence, a mobile out of service or out of range will not be "rung" and the channel will be returned to idle.

3.24 Perhaps the outstanding feature of IMTS is the channel-searching ability which permits mobiles to search automatically over all available channels and lock to a specific channel which is marked idle. This allows the next land or mobile call to be made over the idle marked channel. This principle is analogous to multiple trunking in that it increases the traffic handling capability of a given number of channels.

3.25 Manual signaling and the new IMTS signaling are common to IMTS equipment. This means that thousands of manual and non-IMTS dial mobile units still in service may operate into IMTS systems thereby delaying their obsolescence. Conversely, IMTS mobiles can be served by manual systems which increases their usefulness.

3.26 The mobile subscriber is assigned a conventional 7-digit directory number (NNX-1234); however, his mobile unit is assigned a different 7-digit number which has the local numbering plan area code in place of the office code (NPA-1234). This may be termed the equipment number. The last four digits of the directory number and equipment number are identical. Figure 1 shows the number relationship and the paths for dialing a mobile unit. The equipment number must not be duplicated anywhere, and the last four digits must not be duplicated in a numbering plan area. A central coordinating body must assign and coordinate these numbers for each NPA. The mobile transmits the equipment number automatically on mobile originated calls for the purpose of subscriber station identification. This tells the control terminal if it is a local or a visiting mobile unit and it may be used for billing purposes. There is no restriction to the use of the digit "1" as in some previous mobile telephone equipment; therefore it is theoretically possible to have 10,000 distinctive mobile equipment numbers within each numbering plan area. There are approximately 100 numbering plan areas in the continental United States, which means that 10,000 numbers times 100 NPA's or 1,000,000 distinctive mobile equipment numbers could be assigned to automobile telephone equipment across the nation if there were sufficient radio channels to serve them.

3.3 The IMTS mobile subscriber has three modes of operation available to him. These are Home, Roam, and Manual. Figure 2 illustrates the IMTS control head with the functions described here. Other type control heads are available that provide the same functions using selector switches instead of pushbuttons.

3.31 Home Mode - When an IMTS subscriber is in his local service area, the Home Mode button should be depressed. The mobile unit will automatically search over all of the channels available to the local service area and lock onto the marked idle channel. The mobile subscriber can then initiate or receive dialed calls.

3.32 Roam Mode - An IMTS subscriber traveling within a foreign exchange area that has IMTS should depress the Roam Mode button and select the channels available in that exchange by depressing the appropriate channel buttons. The mobile unit will then search for and lock to the marked idle channel. An IMTS mobile in a foreign IMTS area can be called by an operator and can make local and toll calls with operator assistance. The equipment, however, has the capability to permit the roaming IMTS subscriber to dial calls.

3.33 Manual Mode - The Manual Mode enables the IMTS mobile to accept 600/1500 Hz signaling from a manual system. An IMTS mobile in a manual system area can initiate a call by depressing the push-to-talk button which sends a burst of carrier and lights the lamp at the Mobile Service Operator (MSO) switchboard position. This mode normally uses push-to-talk operation rather than full duplex as in the Home and Roam Modes. However, the IMTS mobile unit will operate full duplex when the push-to-talk button is depressed.

3.34 Mobile to mobile calls in a single-channel system cannot be made with full duplex transmission because the base station receiver cannot accept more than one carrier at a time. Hence, it is necessary to have a procedure that makes the calling and called subscribers aware that a revertive call is in process so that they can use the push-to-talk button. It is also important that upon completion of a revertive call each mobile returns to its previous IMTS mode of operation. These features are provided in IMTS equipment accepted by REA.

4. IMTS - APPLICATIONS TO TELEPHONE SERVICE

4.1 The basic IMTS concept was developed around the use of several channels at one location. With two or more channels the channel-searching technique can be applied for definite improvement

in traffic handling as compared with older type systems having an equal number of channels. The number of base radio channels permitted at one location is determined by the number of mobile subscribers that will be served. A showing must be made to the FCC to justify the proposed number of channels from a traffic loading standpoint.

4.2 Multichannel IMTS systems provide mobile-to-land, land-to-mobile and mobile-to-mobile calls with automatic channel access in each direction. Mobile-to-mobile calls are generally made using two channels and therefore require no special procedure by the subscribers. All calls in the Home and Roam Modes use full duplex operation. However, the equipment can be arranged to permit mobile-to-mobile calls on only one channel as in single channel systems. This increases the traffic handling capability of the system when mobile-to-mobile calls are in progress.

4.3 Although the concept of IMTS is centered around multichannel systems, there are many instances when a single-channel system must suffice. The advantage of channel-searching is lost in a single-channel IMTS system but the compatibility with other IMTS systems is maintained. The mobile units have full duplex transmission, except on revertive calls, and they identify themselves automatically.

4.4 Since the roaming capability of an IMTS mobile subscriber depends on the number of channels with which his mobile unit is equipped, it is important that all IMTS mobile units be capable of operating on the maximum number of channels available in the frequency band of operation. There are eleven channels available in the 150 MC band. IMTS mobiles should be designed for eleven channel operation with the provision for adding channels as required. This provides the mobile subscriber with full roaming capability. This is an REA specification.

4.5 Mobile telephone service should be as nearly like land-line service as possible. Flat rate billing helps achieve this similarity. Use of the system is stimulated by flat-rate billing because subscribers are inclined to make more efficient use of their mobile telephone if they are not charged on a message-unit basis; furthermore, it simplifies billing and record keeping.

4.6 Operator assistance should be made available by some means to all types of foreign mobile units. The extent of service that a mobile can get when roaming in a foreign area is a function of the degree of compatibility which is categorized as "A", "B" or "C". "A" is the minimum degree. It provides for manual completion of calls initiated by mobiles. "B" includes "A" plus operator capability of calling mobiles. "C" includes "B" plus the provision for full two-way dial operation.

4.7 The following controls and indications must appear at the operator's switchboard position for her to have complete control of an IMTS system:

4.71
a. IMTS outgoing jack
b. MTS outgoing jack
c. Incoming Jack
d Incoming call lamp
e. Channel busy lamp
f. Idle channel lamp

4.72 These functions can be provided at the positions of special or Mobile Service Operators (MSO) by interconnecting the switchboard and control terminal using the required cable pairs and interface equipment. When the operators are located remote from the control terminal such as in another town, special means for accessing their services are required.

4.73 The following types of operator access for non-compatible mobiles are presently available:

4.731 The revert-to-operator method allows a foreign mobile to access a regular toll trunk to a regular operator when unmodulated carrier or incompatible "off-hook" signals are received at the base station control terminal. This permits the mobile to call an operator but does not permit the operator to call a mobile. This is compatibility "A". The major drawback to this method is that the operator's incoming call lamp is sometimes lighted by spurious radio signals. Since the operators that handle these calls are regular toll service operators and not Mobile Service Operators, they cannot distinquish if an incoming call is from a mobile or land subscriber. Consequently, when an operator's lamp lights permanently or flashes often due to spurious radio signals, she may turn down the trunk thinking it is in trouble. Although this method makes it possible to use regular toll trunks, the problems presented to the operators and their inability to place calls to a mobile make it undesirable.

4.732 Another method of providing operator access to roaming mobiles employs a dedicated trunk to a Mobile Service Operator who is trained to handle mobile calls. The trunk is dedicated in the sense that it is used only for calls to or from mobile units. The trunk is permanently connected between the radio control terminal and the MSO switchboard position. It provides the requirements listed in 4.71. The dedicated trunk makes it possible for a roaming mobile to place and receive calls with the assistance of the Mobile Service Operator. This is compatibility "B". The operator can signal IMTS or manual mobiles. Since the Mobile Service Operator is trained to handle mobile calls, she is able to interpret and react promptly to spurious signals and other conditions peculiar to mobile telephone service.

4.733 The selector-level approach also provides compatibility "B" when used in conjunction with the revert-to-operator feature. This method requires two selector levels at the end office--one level for manual signaling and one for IMTS signaling. The desired type of signaling can be selected by the regular toll operators by dialing a special digit prior to the mobile number. This is accomplished over existing toll trunks.

4.74 All of these methods of operator access require some special type of interface equipment.

4.741 The revert-to-operator feature requires a means for artificially pulsing the central office equipment to access the operator trunks.

4.742 The dedicated trunk method requires interface equipment to permit the functions to be carried over one two-way trunk. Each radio channel requires a separate dedicated trunk.

4.75 A dedicated trunk may be more expensive than using regular toll trunks; however, the extra expense seems justifiable in view of the advantages over the regular trunks. Some of these advantages are summarized here:

4.751 The operator has full supervision of the radio channel, that is, she can seize it and restore it to idle, thus eliminating the need for an automatic time-out which wastes "air" time.

4.752 Regular operators need not be trained to handle mobile calls.

4.753 Regular operators are spared the harassment of answering trunk seizures due to false "hits" to the radio channel caused by extraneous signals.

4.754 All jacks and indicator lamps required for complete IMTS operation are available to the operator.

4.755 A dedicated trunk is never busy when the radio channel is idle.

5. RF SYSTEM DESIGN

5.1 A mobile telephone system is no better than the transmission quality obtained throughout its service area. The radio coverage must include locations required by the subscribers. However, the area of coverage should not be designed to extend beyond the required service area. Careful consideration must be given neighboring communities served by other telephone companies so that an orderly arrangement of mobile telephone systems may develop.

5.11 The radio transmission coverage over level or gently rolling terrain can be predicted with reasonable accuracy. For example, a 50 watt base station transmitter connected to a 6 db gain antenna mounted on a 150-to 200-foot tower will generally give good two-way transmission with a 25-watt mobile unit operating 25 to 35 miles from the base station.

5.12 Radio transmission throughout an area having rugged terrain is difficult to predict with any degree of accuracy. Knowledge of the terrain is necessary if a prediction is to be reasonably accurate. The FCC requires profiles of radials extending from the base station transmitter location at intervals of 45 degrees from true north. The required information and the methods for obtaining it are set forth in paragraphs 21.115 and 21.116 of Part 21 of the FCC rules. This Part is included in Volume VII of the FCC Rules and Regulations and can be obtained from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C., 20402. The price is $2.00. Additional information may be found in REA TE & CM-940.

5.2 The radio base station usually includes the transmitter and receiver with associated power supplies. However, base station receivers associated with the system may be installed at locations separate from the transmitters. This is often done in urban applications to improve the mobile talkback range. Each satellite receiver is connected to the control terminal by a cable pair which carries both audio and control functions.

5.3 The facility used to connect the transmitters and receivers with the control terminal must have good voice frequency response characteristics to provide good speech transmission and allow the supervisory and dialing tones to perform their functions. Some systems rely on d-c voltages of varying magnitude for control functions and, therefore, require a wire facility. Circuits derived by cable pairs over distances in excess of 18 kf must be appropriately loaded.

5.4 The idle channel in an IMTS system is marked by transmitting a continuous 2000 Hz tone from the base station. The FCC designation for tone transmission using frequency (or phase) modulation is F2 while the designation for commercial telephony is F3.

5.41 The emission designation for tone and speech tranamission in IMTS systems is 15F2 and 16F3, respectively. The number prefix denotes the necessary bandwidth in kilohertz. Its derivation is explained in Part 2, Subpart C of the FCC Rules and Regulations.

5.42 When three or more IMTS transmitters are installed at the same location, intermodulation products may develop which cause the idle mark signal to appear on a channel that is not in use at the moment. For example, suppose that three transmitters having frequencies f_1, f_2, and f_3 are installed at the same location. At a particular time f_1 is marked with idle tone while f_2 is busy. The intermodulation products of f_1 and f_2 can result in a frequency f_3 with idle mark tone even though the f_3 transmitter is off. A mobile receiver in the vicinity of the transmitters would see f_3 marked with "idle" tone and lock onto it in its searching procedure. The same problem may arise when other mobile radio services are operating in the area. To overcome this problem the base station transmitters that are not marked idle or in use are turned on at a very low output power (normally 0.5 watt) with no modulation. This low level carrier provides a quieting signal to the mobile receivers and suppresses any intermodulation signal that may appear at that frequency. This type of emission is designated F0 and should be requested in the application to the FCC for a construction permit when three or more transmitters will be installed at the same location.

6. EQUIPMENT COSTS

6.1 The following is an approximation of IMTS equipment prices.

6.11 Base station complete with 50-100 watt transmitter, receiver and duplexer for each channel:	$2000 to $3000
6.12 Control terminal--equipped with:	
a) One channel to serve 30 mobile numbers*	$6500 to $7500
b) Two channels to serve 60 mobile numbers*	$10,000 to $15,000
c) Three channels to serve 120 mobile numbers*	$19,000
d) Four channels to serve 240 mobile numbers*	$26,000

*This implies that the stated quantity of mobile units may be customer-dialed through the central office equipment and control terminal. There is no limit to the quantity of mobile units that can be served by a Mobile Service Operator. Furthermore, there is no limit to the quantity of mobile units that may initiate dialed calls insofar as the technical limitations of the control terminal are concerned.

6.13 Mobile units complete with choice of color telephone instrument and equipped for one to eleven channels as specified:	$1300 to $1600
6.14 Base station gain antenna with 150 feet of transmission line:	$350 to $500
6.15 Self-supporting tower, 150 feet, installed:	$3000
6.16 Guyed tower, 150 feet, installed:	$1500

6.2 When pricing a multichannel system, the cost of a base station should be included for each additional channel along with the cost of the applicable control terminal.

6.3 The price of a mobile unit equipped for one channel is comparable to that of the former dial mobile units. The design is such that the cost of equipping additional channels is only $15 to $30 per channel.

6.4 The annual cost including maintenance and depreciation is comparable to that of the former systems. REA TE & CM-218,"Plant Annual Cost Data for System Design Purposes," shows $10 per month per mobile unit and $47.50 per month for the base station which includes the (1) control terminal, (2) radio base station, and (3) 150-foot tower and antenna.

6.41 The radio base station and mobile units are generally maintained on a fixed-price basis under contract with the supplier. However, the IMTS control terminal is generally maintained by telephone company personnel because it is similar to central office equipment.

IMTS SIGNALING- SE TO MOBILE

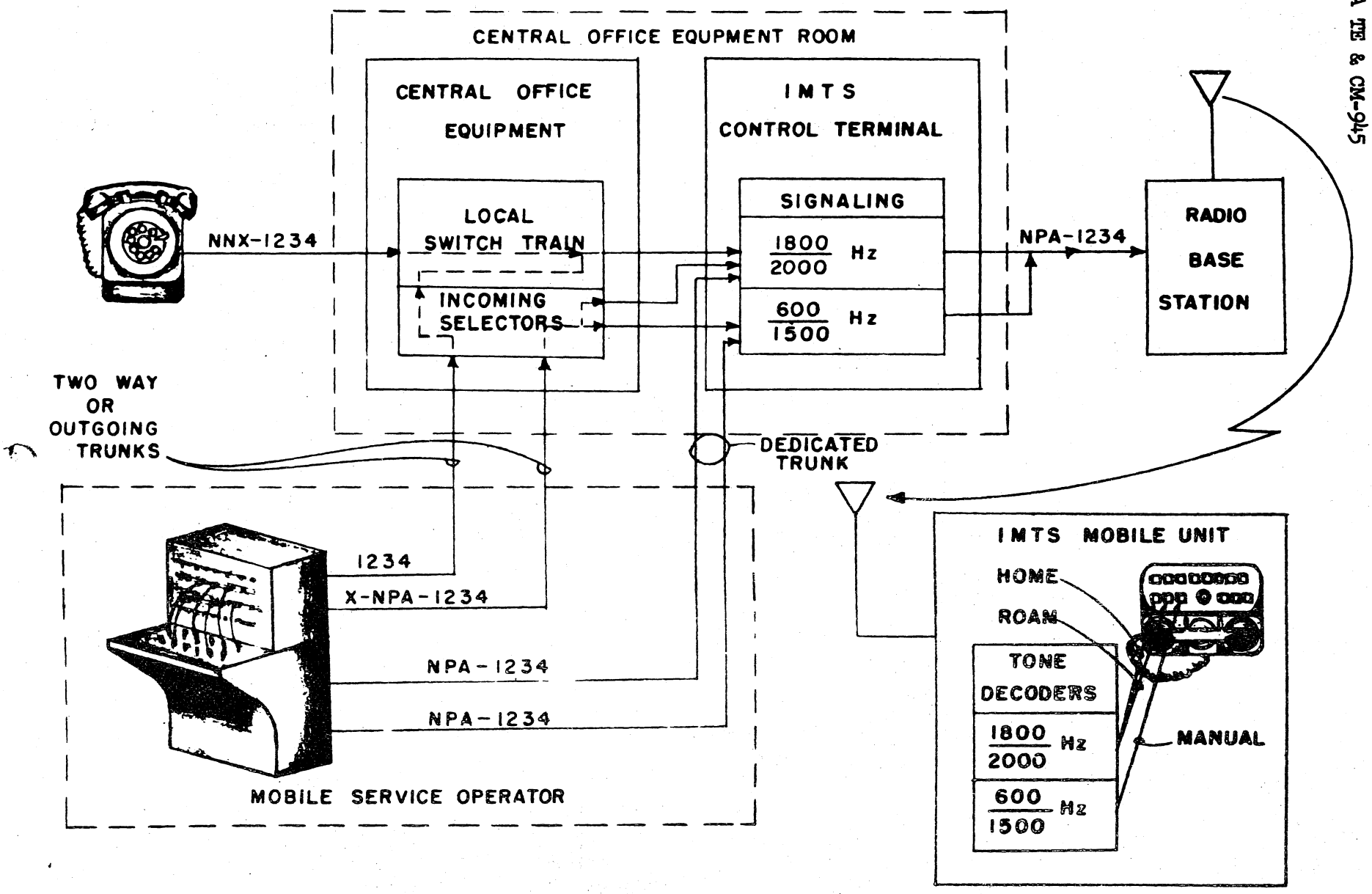
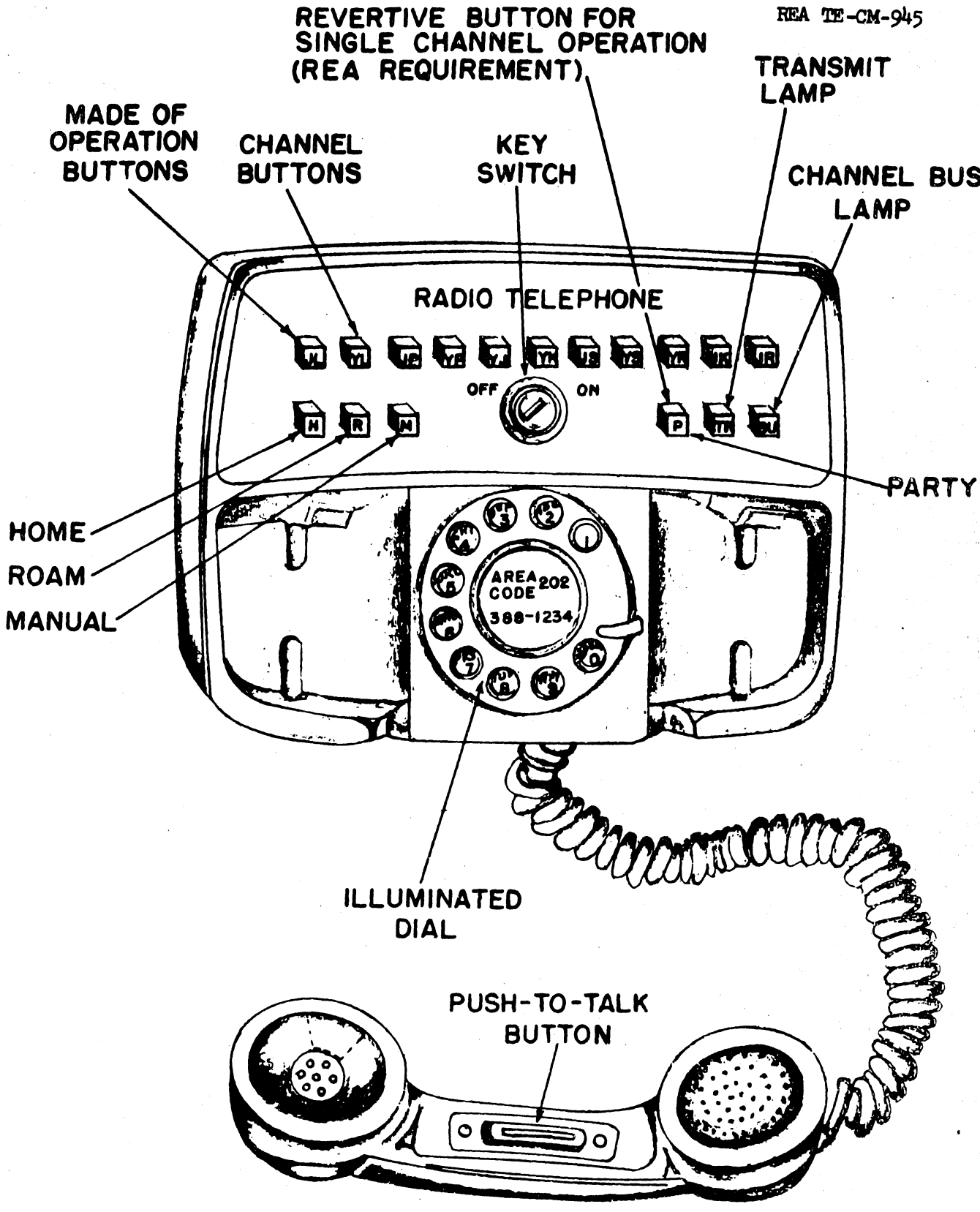


FIGURE 1



THE IMTS CONTROL HEAD

FIGURE 2