PUB 43301

PRELIMINARY

Bell System

Transmission and Radio Engineering

TECHNICAL REFERENCE

Domestic Public Land Mobile Telephone Services Customer Provided Dial Station

Interface Specification

June 1971

Revised - March 1973

Reissued - Corrected -- May 1974

ENGINEERING DIRECTOR-TRANSMISSION AND RADIO SYSTEMS

NOTICE

This Technical Reference is published by American Telephone and Telegraph Company as a guide for the designers, manufacturers, and consultants of customer-provided systems and equipment which connect with Bell System communications systems or equipment. American Telephone and Telegraph Company reserves the right to revise this Technical Reference for any reason, including, but not limited to, conformity with standards promulgated by ANSI, FCC, EIA, CCITT, CCIR, or similar agencies; utilization of new advances in the state of the technical arts; or to reflect changes in the design of equipment or services described therein. The limits of responsibility and liability of the Bell System with respect to the use of customer-provided systems and equipment are set forth in the appropriate tariff regulations.

If further information is required, please contact:

Engineering Director - Transmission and Radio Systems
American Telephone and Telegraph Company
195 Broadway
New York, New York 10007

Customer Provided Domestic Public Land Mobile Telephone Dial Stations - Interface Specifications

Table of Contents

Customer Provided Domestic Public Land Mobile Telephone Dial Stations - Interface Specification

1. GENERAL

1.1 Intrastate Tariffs filed by the Bell System provide for customer-provided mobile telephone station equipment operating with Bell System mobile telephone systems. Connection is made through radio transmission to and from base stations furnished, installed, and maintained by the Telephone Company and operating on frequencies authorized by the Federal Communications Commission for wireline common carriers. These base stations are connected to the Bell System telecommunications network.

1.2 Responsibility of the Telephone Company

The Tariffs state that: The Telephone Company shall not be responsible for installation, operation or maintenance of any terminal equipment or communications systems provided by a customer, authorized user, or joint user. Long distance message telecommunications service is not represented as adapted to the use of such equipment or systems and where such equipment or system is connected to Telephone Company facilities the responsibility of the Telephone Company shall be limited to the furnishing of facilities suitable for long distance message telecommunications service and to the maintenance and operation of such facilities in a manner proper for such telecommunications service. Subject to this responsibility the Telephone Company shall not be responsible for (i) the through transmission of signals generated by such equipment or system, or for the quality of or defects in, such transmission, or (ii) the reception of signals by such equipment or systems or (iii) address signaling where such signaling is performed by customer-provided tone-type signaling equipment. The Telephone Company shall not be responsible to the customer or authorized user

or joint user if changes in protection criteria contained in the tariffs or in any of the facilities, operations, or procedures of the Telephone Company render any facilities provided by a customer, authorized user or joint user obsolete or require modification or alteration of such equipment or system or otherwise affect its use or performance.

1.3 Responsibility of the Customer

The Tariffs state that: Where long distance message telecommunications service is available under this tariff for use in connection with terminal equipment or communications systems, provided by a customer, authorized user or joint user, the operating characteristics of such equipment or systems shall be such as not to interfere with any of the services offered by the Telephone Company. Such use is subject to the further provisions that the equipment or systems provided by a customer, authorized user or joint user does not endanger the safety of Telephone Company employees or the public, damage, require change in or alteration of, the equipment or other facilities of the Telephone Company; interfere with the proper functioning of such equipment or facilities; impair the operation of the Telephone Company's facilities or otherwise injure the public in its use of the Telephone Company's services. Upon notice from the Telephone Company that the equipment or system provided by a customer, authorized user or joint user is causing or is likely to cause such hazard or interference the customer shall take such steps as shall be necessary to remove or prevent such hazard or interference.

1.4 The Bell System is undergoing an orderly conversion from manual to dial operation of its domestic public land mobile telephone service. Dial operation in Bell System service areas is, with a few

exceptions, of the type known in the industry as "IMTS" (Improved Mobile Telephone System). It is basically different from other types of "dial" operation in that radio channel selection is done automatically. This Technical Reference, therefore, addresses itself to interface specifications of customer-provided mobile telephone dial stations connected to "IMTS" type systems known in the Bell System as the MJ and MK systems. However, information has been included for use in manual operation in areas still offering manual service.

2. SYSTEM DESCRIPTION - MJ and MK MOBILE TELEPHONE RADIO SYSTEMS

2.1 The MJ system (operates in the 152 MHz - 162 MHz band on 11 channels) and the MK system (operates in the 450 MHz - 460 MHz band on 12 channels) provide for dialing of calls both to and from the mobile station. Also full duplex operation is provided so that its user will not have the inconvenience of pressing a button to talk. Automatic channel selection features of these systems make it unnecessary for the mobile customer to search for a radio channel on which to make a call, and land-to-mobile calls can be completed whenever any channel is idle. In most situations, the MJ/MK systems customer can place or receive a telephone call in his home service area as though he were at a wire-line telephone, using much the same procedures.

2.2 The major elements of the MJ or MK system are shown in the block diagram of Figure 1. The control terminal, located in a dial central office, is interconnected between the dial switching equipment and the base station radio units and serves all channels equipped in the area (from one to a maximum of eight). In addition to its connection to the dial office, the control terminal may have a trunk connection to a switchboard used for assistance on certain types of calls. The control terminal performs a number of control, signaling, and switching functions. It also regulates the transmission levels of speech and provides a two-wire to four-wire transition in the speech path. Wire line or carrier facilities interconnect the control terminal with the base station radio receivers and transmitters if they are located some distance away from the control terminal.

2.3 The general layout of the base station radio equipment does not differ appreciably from that used in the older (manual) mobile systems. In metropolitan cities requiring coverage of an area perhaps 30 or 40 miles

in diameter, each channel will be equipped with a high output power (250-watt MJ or up to 120 watt MK) base transmitter. Up to eight base station receiver locations may be situated about the area, as required, to compensate for the lower power output of the mobile station transmitters. When a call is in progress each receiver sends back to the control terminal an indication of its signal-to-noise ratio and selection arrangements in the control terminal then select the receiver which will provide the best transmission for the call.

2.4 Smaller cities having less demanding coverage requirements will normally use a low-power (50-watt or less) base transmitter with a single base receiver location on each channel. In some cases, however, use of additional receiver locations may be required to ensure satisfactory transmission in the opposite direction.

2.5 The communication circuit is extended from the base transmitter to the mobile set in the car by one radio frequency, as shown in the diagram of Figure 1. The car transmits back to the base receiver at another frequency; these two frequency assignments constitute one two-way radio channel.

2.6 The vehicular mobile set of the MJ and MK systems is made up of a radio transmitter-receiver combination unit, plus the control and supervisory units necessary for dialing, channel switching, logic operations, and selective signaling. The mobile equipment is arranged for full duplex operation with the transmitter on the air throughout a call, and can be equipped. for operation on at least all of the channels provided in its home service area. In addition, customers who wish service when they drive into other mobile telephone service areas that offer service to transients may have

their sets equipped for operation on all radio channels authorized for wireline common carriers that is, 152 MHz - 162 MHz (11 channels) on MJ or 450 MHz - 460 MHz (12 channels) on MK provided that FCC approval has been obtained.

2.7 The MJ/MK systems are designed to connect to dial offices and thus to the telecommunications network. Each mobile station is assigned a conventional line terminal (telephone number) in the central office. This permits the local office to accord the mobile station the same treatment as a landline telephone in regard to dialing privileges, automatic number identification, message accounting, etc. When in his home area, an MJ/MK customer may dial through the central office to reach any number that a landline customer can reach on a dial basis.

2.8 The dial mobile stations in MJ and MK systems have telephone numbers similar to those of a land telephone station (e.g., 201-258-1734). These 10 digit numbers (area code plus central office code plus mobile line assignment in the dial office) will not be duplicated in any mobile telephones in the home numbering plan area, although the last seven digits may be repeated in other areas. On a local call from a land telephone station to an MJ/MK home mobile having the above type number, the land customer need dial only the last seven digits to be connected to the mobile station. On a long distance call from another area, all 10 digits must be dialed. In both situations calling procedures do not differ from those used to call a conventional telephone. In each case, the control terminal determines the station number dialed by translating the central office assignment. The terminal deletes the central office code and generates a seven digit number consisting of the area code plus the four

digit station number and outpulses this seven digit number, to which the mobile selector has been set to respond.

2.9 The base station arrangements for the MJ/MK systems handle from one to a maximum of eight channels in any one mobile area. The upper limit, in this case, is established by the fact that any area requiring this number of channels will itself be surrounded by smaller cities and towns which also require service. It is possible, however, to serve an area by two systems, such as an eight channel and a four channel MK system, for example.

2.10 A basic feature of operation of the MJ/MK systems is the automatic selection and marking of a radio channel for each call. Whenever there are channels idle and available for traffic, the control terminal selects one and turns on its base transmitter carrier modulated by "idle marking" tone. All idle mobile sets hunt over their channels until the idle tone is detected, and then camp on this marked idle channel. The next call in either direction is then established over this channel, with the involved mobile customer's set remaining locked to it. In the process of completing this call, the control terminal moves the idle tone to some other available channel, again causing all idle mobile sets to step to it in readiness for another call. Since this feature makes it unnecessary for the mobile customer to monitor channels in order to find an idle one, a degree of privacy is afforded. If all the channels are busy the mobile customer gets a busy lamp indication, instead of dial tone, when he attempts to place a call. A land customer placing a call to a radio system where all channels are busy, will get the conventional "all trunks busy" tone indication.

2.11 In the control terminal, a line circuit is assigned exclusively to each mobile station equipped in the "home" base station area. During each mobile originated call, the mobile station outpulses its assigned number which is then compared in the control terminal with the locally assigned numbers. This is done to determine whether the mobile station is a "home" customer and is to be given access to a specific line circuit. In addition, a parity check is made of the received digits from the mobile as an error check, prior to switching the radio channel to the line circuit of the mobile station.

2.12 On a land-originated call to an MJ or MK type mobile station, the control terminal outpulses the seven digit number of the mobile station (area code and four digit station number). The call is then completed or abandoned by the control terminal depending upon the return of a signal acknowledging receipt of the call by the MJ or MK mobile. On calls placed by an MJ or MK mobile, the connection is extended through the control terminal line circuit to the dial office. If the mobile's identification number does not match that of a "home" mobile station line assignment or if the parity check shows distortion in transmission, the call attempt may be routed to the mobile service operator for completion. An exception to this will occur in cases where the terminal has been equipped with an option for automatic handling of calls made by customers from other mobile areas. In this case, the call will be routed to a central office line circuit having the appropriate call billing treatment and dial tone returned. Also, on systems used for local service only, access to a mobile service operator by a transient customer may be precluded.

2.13 The basic elements of the mobile set used in the MJ or MK systems are the control unit, the radio and supervisory units, an antenna, and the usual interconnecting cables.

2.14 The supervisory unit is an essential part of the equipment. It performs the logic and tone signaling functions mentioned previously. Included in the supervisory unit is a selective signaling decoder which causes the mobile to respond to its seven-digit number when it is called. On mobile-originated calls, the unit sends this same number into the control terminal as identification, so that the call will be routed to the proper customer's line circuit for completion.

2.15 The control unit is the equipment that interacts directly with the customer. It includes a handset and controls for selection of various operating modes. In MJ systems, the typical control unit includes one group of three mode selection pushbuttons (designated H, R and M for the Home, Roam and Manual modes) and a second group of channel selection pushbuttons, one for every channel allocated in that frequency band. In the Home mode, the supervisory unit causes the mobile set to hunt for a "marked idle" channel over the channels assigned in the "home" area. This hunting sequence is prewired in the supervisory unit. When the customer travels into service areas other than his home area, he puts the set in the Roam mode and then selects, by depressing the appropriate pushbuttons, the channels operating in that particular service area. The supervisory unit will then hunt for a "marked idle" tone only over the channels selected by the customer. If no channels are selected and the MJ mobile is in the Roam mode, it will hunt across all channels. In addition the MJ set includes a Manual mode used when the customer travels into service areas that have not yet been converted to dial operation. The Manual mode by-passes the automatic scanning and dialing features. The customer then selects one idle channel by means of the channel pushbuttons. The control unit must also include a "transmitter on" indication (FCC Rules) which is activated any time that the radio is radiating power. In addition, most control units include, as a user convenience, a "busy" indication which, upon going off-hook in

in the IMTS modes, shows whether the service request from that radio has been properly recognized by the base station. Further, for system design reasons, the use of an indication showing idle channel availability in the on-hook condition or the employment of devices enabling queuing of call attempts during all channels busy conditions is not acceptable.

2.16 The MK control unit is equipped with the H and R mode only, since MK systems are not compatible with manual sets.

2.17 Both MJ and MK control units may be furnished with pre-selected Roam mode channel hunting sequences. However, in areas having overlapping service areas, lack of individual channel selection controls usually precludes reliable land to mobile roaming service, and allows random access to any base station on mobile to land calling. Some subscribers may find the inability to place calls through a specific base station objectionable.

2.18 The customer of an MJ or MK mobile system, when using his car in his home area, can make or receive calls entirely on a dial basis. When he travels into a distant area that offers service to transients, (some MK systems are used for local only service) calls addressed to him are handled by the mobile service operator since some special attention is likely to be necessary in locating a roaming vehicle. Mobile telephone originated calls may either be given local only, or automatic local and toll dial service (at the option of the local Telephone Company) or these calls may be handled by the operator who can record billing information. In a manual mobile system area, of course, all calls are operator-handled. If a manual mobile roams into an MJ system area and attempts to make a call, the control terminal is usually arranged to route the call to the operator for completion; this is not the case in the MK system, which is not equipped to service manual mobile units. However, a small but growing number of MJ systems are no longer offering service to manual mobile telephones.

2.19 Both MJ and MK mobiles offer the user the ability to turn off the transmitter by going on-hook (handset in the cradle) or by turning the set off (key switch). Going off-hook (handset removed from cradle) turns the transmitter on whenever the radio unit is camped on a marked idle channel in the IMTS modes or while the push-to-talk switch is operated in the manual mode.

3. FCC CONSIDERATIONS

3.1 Domestic Public Land Mobile Telephone Service offered by the Bell System is subject to the Federal Communications Commission's Rules and Regulations which also apply to manufacturers and users of mobile radio equipment. As a guide for the designers, manufacturers and consultants of customer-provided mobile telephone dial stations, this section covers some pertinent aspects of the Rules and Regulations. For more details, the Rules should be consulted, in particular Parts 2, 15 and 21.

3.2 The FCC under its Rules, indicates that it is necessary for the Commission to ascertain that the equipment meet the technical operating standards set forth in treaties, statutes and its own Rules. To that end, the Commission has set procedures involving either tests conducted by Commission personnel or test data submitted to the commission by the manufacturer. Unless the Commission has "type approved" or "type accepted" the equipment, the user cannot be licensed. The Rules should, therefore, be carefully reviewed with respect to required procedures, types of data and technical standards.

3.3 According to the FCC Rules (Part 21), a radio transmitter cannot be operated without prior authorization by the FCC. Customer-provided equipment, in addition to having been "type approved" or "type accepted" by the FCC, will also require an application for a license by the proposed user. It must be emphasized that the application for an FCC license should also include a showing of definite arrangements having been made for the requested mobile units to obtain communications service upon the frequencies requested through an established base station (licensed in the name of the local Telephone Company). This means that before applying for an FCC license, the

applicant must obtain a letter from the local Telephone Company which indicates availability of service and the operating frequencies of the home service area base stations. Other requirements for a license are listed in the FCC Rules.

3.4 The frequencies allocated by the FCC to the Telephone Companies are as follows:

MJ System Frequency Assignments

Channel Designations	Base Station Transmit (MHz)	Mobile Station Transmit (MHz)
JL	152.51	157.77
YL	152.54	157.80
JP	152.57	157.83
YP	152.60	157.86
YJ	152.63	157.89
YK	152.66	157.92
JS	152.69	157.95
YS	152.72	157.98
YR	152.75	158.01
JK	152.78	158.04
JR	152.81	158.07

MK System Frequency Assignments

Channel Designation	Base Station Transmit (MHz)	Mobile Station Transmit (MHz)
QC	454.375	459.375
QJ	454.400	459.400
QD	454.425	459.425
QA	454.450	459.450
QE	454.475	459.475
QP	454.500	459.500
QK	454.525	459.525
QB	454.550	459.550
QO	454.575	459.575
QR	454.600	459.600
QY	454.625	459.625
QF	454.650	459.650

3.5 Maximum frequency tolerances, emission limitations, maximum output power, and modulation requirements are technical standards that are set forth by the FCC. Some of these will be covered in the subsequent sections. In addition the FCC also defines the tolerances of frequency measuring or calibrating apparatus used to set and check the frequency of the equipments' transmitted output signal, and the qualifications of the personnel maintaining equipment. For more details the FCC's Rules should be reviewed.

4. INTERFACE SPECIFICATIONS - GENERAL CONSIDERATIONS

4.1 This interface specification provides information needed to meet the following criteria:

- Compatibility between the customer-provided mobile telephone station and the Telephone Company provided mobile telephone system.
- Lack of interference between the customer-provided equipment and other mobile telephone customers or other services.
- Compliance with the FCC's operating technical standards and procedures as set forth in its Rules and Regulations.
- Provision of a good grade of service within the constraints imposed by the current scarcity of radio channels.

4.2 The first three criteria above, relate to the conditions under which the connection of customer-provided mobile telephone equipment to the Bell System telecommunications network can be accomplished. The technical specifications in this Technical Reference delineate these conditions. The fourth criterion above is more difficult to define in terms of interface specifications because it involves a greater degree of judgment. Man-made and terrain obstructions, changing atmospheric conditions, ambient

noise and the motion of the mobile telephone station through city streets and highways do not lend themselves to easily handled mathematical relationships or to a limited number of measurements that accurately predict system performance. Therefore, the design of mobile telephone systems is to a large extent based on judgement, experience and empirical concepts. As a guide for the designers, manufacturers and consultants of customer-provided mobile telephone stations and in the interest of good service, this Technical Reference also includes some technical specifications that define the performance of the Bell System MJ and MK type mobile telephone stations which are based on Bell System experience and the state-of-the-art existing at the time MJ and MK systems were first made available for service.

4.3 In view of the above, this Technical Reference defines interface specifications into two categories. The first is called "Required Interface Specification" and relates to the first three criteria in section 4.1. The second, "Suggested Interface Specification" related to the fourth criterion in section 4.1, is included in the interest of providing good service to the customer and for the guidance of the designers, manufacturers and consultants of customer-provided mobile telephone stations.

5. INTERFACE SPECIFICATIONS - MK MOBILE TELEPHONE SYSTEM - RADIO UNIT

5.1 As indicated in Section 4.3, interface specifications are defined in two categories, that is, "required interface specifications" and "suggested interface specifications". These cover radio frequency and audio frequency characteristics of the radio unit operating with an MK mobile telephone system.

5.2 Mobile Transmitter

5.2.1. Environmental Requirements

All required interface specifications covered in the following sections shall meet all the combinations of conditions listed below:

a) DC supply voltage (at battery): 13.7 volts ± 10%

b) Ambient temperature (still air): -20°C to +50°C (-4°F to +122°F)

c) Relative humidity: 5 to 90 percent

5.2.2 RF Output Power

When switched to each of 12 channels in turn, the RF power output shall be:

required minimum output: 12 watts

suggested output: at least 16 watts and shall not vary more than ±0.5dB except under severe environmental conditions

suggested maximum output: 25 watts - This upper bound is established to minimize interference to nearby base stations operating on the same channel.

5.2.3 Required Minimum Operating Delay

After an adequate warm-up period, the equipment shall deliver at least 70 percent of its full RF output power within 100 msec after receiving a "transmitter on" command. It shall also be capable of delivering 70 percent of full output power within 1 minute after being activated by the control unit "ON" switch.

5.2.4 Required Tone Sensitivity

The tone input (at 1336 Hz, 1633 Hz and 2150 Hz) levels shall cause a minimum of ±3.3 kHz deviation of the RF carrier as measured at the antenna jack (see Figure 2 for pre-emphasis response).

5.2.5 Suggested Speech Sensitivity

The maximum sensitivity at the speech input shall be such that the input level at 1000 Hz shall cause ±3.3 kHz deviation of the RF carrier as measured at the antenna jack (see Figure 2 for pre-emphasis response).

5.2.6 Required Modulation Deviation Limiting

For audio inputs applied over the transmitter speech input lead, the equipment shall be capable of adjustment to limit the deviation to ±5 kHz. When the equipment is adjusted for ±5 kHz limiting, it shall operate in conformance with FCC Rules on deviation limiting at all input frequencies and levels.

5.2.7 Suggested Audio Distortion Limits

Audio frequency distortion shall not exceed 5 percent in transmitting, when modulated with a 1000-Hz tone input to produce ±3.3 kHz deviation.

5.2.8 Modulation Stability

In transmitting, in the range below deviation limiting (at least up to ±3.3 kHz deviation), the transmitter carrier deviation produced by a constant amplitude 1000 Hz tone shall not vary more than:

required specification: ±15%

suggested specification: ±10% except under extreme environmental conditions where it may not vary more than ±15%

5.2.9 Suggested Transmitter Audio Frequency Characteristics

Figure 2 shows the allowable limits of audio input (below limiting) in dB referenced to the audio input level at 1 kHz required to provide ±0.5 kHz deviation.

5.2.10 Required Type of Modulation and Modulation Symmetry

The equipment shall be capable of transmitting phase modulated RF signals with a maximum deviation of ±5 kHz. The modulation shall be symmetrical, i.e., there shall be no more than 10 percent difference between positive and negative swings of the carrier at any level of modulation, and no obvious dissymmetry when viewed with a suitable detector and oscilloscope.

5.2.11 Suggested Limit of FM Hum and Noise

FM hum and noise modulation on the RF carrier shall be at least 60 dB (with C-message weighting) below the level of a 1000-Hz tone causing ±3.3 kHz deviation.

5.2.12 Suggested Limit of Residual AM Modulation

The peak voltage level of any residual AM modulation on the RF carrier shall be at least 40 dB below the dc voltage obtained by rectification of the modulated carrier.

5.2.13 Suggested Margin of Drive

A 6-dB reduction in gain of any individual oscillator, multiplier or driver stage shall not decrease the RF output by more than 2 dB. Alternately, the power output shall not drop more than 10 percent from the initial value under extreme environmental conditions.

5.2.14 Harmonic and Spurious Emissions

Required specification: see FCC Rules and Regulations

Suggested specification: harmonic and spurious emissions shall be at least 90 dB below the unmodulated carrier, as radiated or as measured at either the antenna jack or any lead on the external connector, with the transmitter terminated in a 50 ohm shielded resistive load. The radiation requirement shall be met at the existing environmental conditions of the test site.

Note: Care should be taken to limit to acceptable levels emissions and spectrum noise falling in the mobile receiver's frequency range.

5.2.15 Spectrum Noise Suppression

Required specification: see FCC Rules and Regulations

Suggested specification: The RF spectrum noise suppression at 25 kHz (or more) removed from the carrier frequency shall be at least 70 dB. At frequencies 5 MHz removed, this noise suppression shall be at least 117 dB. This suppression is defined as the difference (b-a) in dB when these quantities are measured as outlined below, using a signal generator and a companion receiver tuned 25 kHz and farther away from the radio transmitter carrier frequency.

(a) (dBw) = A modulated on-channel signal generator input to the companion receiver, adjusted to give a 20 dB tone (receiver audio output when carrier is modulated by 1000 Hz test tone to give $\pm$3.3 kHz deviation) to-noise ratio. (Modulation removed from carrier and noise measured with a 3A type Noise Set, or equivalent, C message weighting, in the absence of interference from the transmitter.)

(b) (dBw) = The interfering transmitter's carrier signal, at the companion receiver's input, adjusted in level so that its accompanying noise decreases the quieting produced by the on-channel unmodulated carrier (in b) by 2 dB. This test should be made both with the carrier of the interfering transmitter unmodulated and modulated by a 1000 Hz tone which produces ±3.3 kHz deviation.

5.2.16 Suggested Intermodulation Conversion Loss

The third-order ((2A-B) etc.) conversion loss in the output stage of the equipment shall be at least 4 dB. Attainment of this conversion shall not be dependent upon critical tuning or loading adjustments.

5.2.17 Frequency Stability

Required specification: ±0.0005% (see, FCC Rules and Regulations)

Suggested specification: Carrier frequency determining circuits shall maintain the equipment within ±0.00035% of its assigned channel frequency within 10 seconds after the application of primary supply voltage. The frequency stability of the equipment shall be such that it can be guaranteed to hold within these ±0.00035 percent limits for a period of at least one year without any readjustment to compensate for drift or aging of crystals, or for variations in supply voltage or ambient temperature within the environmental conditions encountered by the mobile station. Variation due to temperature aging and setting capability shall be separately specified such that the R.S.S. (root of

sum of squares) of the errors due to each shall not exceed limits of ±0.00035 percent.

Note: FCC Rules and Regulations specify that measuring or calibrating devices used to determine compliance, shall have an accuracy within one-half of the allowed frequency tolerance of the transmitter being measured. It is suggested that this requirement apply to measuring devices only and that calibrating devices have an accuracy one order of magnitude better than the allowed frequency tolerance of the transmitter being measured. This is a more stringent requirement than the FCC's but gives a greater assurance of compliance with the Rules.

5.3 Mobile Receiver

5.3.1 Environmental Requirements See Section 5.2.1

5.3.2 Suggested RF Sensitivity

The equipment shall have receiving sensitivity of at least -140 dBw on all channels, where sensitivity is defined as the RF input at the antenna jack to provide 12 db of quieting at the receiver output with C-message weighting. When switched to each of the 12 channels in turn, the sensitivity shall not vary more than ±0.5 dB. In addition, at least 20 dB tone-to-noise ratio with C message weighting shall be produced by -140 dBw (at the antenna jack) modulated by 1 kHz at ±3.3 kHz deviation. For extreme environmental conditions, the sensitivity shall be not less than -138 dBw (C-message weighting)

5.3.3 Suggested Limit on Hum and Noise Level

Hum and noise amplitude in the audio output shall be at least 60 dB below the audio output produced by a carrier deviated ±3.3 kHz with a 1 kHz tone using C-message weighting.

5.3.4 Suggested Modulation Acceptance Bandwidth

The modulation acceptance or "nose" bandwidth, as measured by the single-frequency limiter-current method at the 6-dB down points, shall be at least ±6.0 kHz at 25°C, at least ±5.0 kHz under extreme environmental conditions. In addition, the 8.0 dB points shall be at least ±5.5 kHz under extreme environmental conditions.

5.3.5 Suggested Protection Against Single-Signal Interference

The tone-to-noise ratio (C-message weighting) at the audio output of the receiver when receiving an on-channel weak signal (20 dB tone-to-noise, C message) shall not decrease by more than 2.0 dB in the presence of an interfering signal either unmodulated or modulated (±3.3 kHz deviation by a 1 kHz tone) at the frequency and level shown below:

	Level relative to on-channel signal	Frequency difference between on-channel and interfering signal
	+80 dB	±25 kHz or greater
	+120 dB	± 5 MHz or greater
except	+85 dB	±10 MHz

5.3.6 Suggested Intermodulation Performance

When subjected to an input of two unwanted RF carrier signals at -64 dBw amplitude, 25 kHz and 50 kHz away from the receiver tuned frequency, the amplitude of the resultant intermodulation product as measured by calibrated limiter current, shall not exceed -142 dBw. This is an intermodulation conversion loss of 78 dB.

5.3.7 Suggested High Signal Level Intermodulation

The intermodulation conversion loss of the receiver at input signal levels up to -36 dBw shall be at least 40 dB.

5.3.8 Undesired Radiated Power

Required specification: see FCC Rules and Regulations

Suggested specification: any RF signals emitted by the receiver shall not be above -117 dBw as measured across a 50-ohm termination connected to the antenna jack.

5.3.9 Required Type of Modulation

The equipment shall be capable of receiving phase modulated RF signals with a maximum deviation of ± 5 kHz.

5.3.10 Suggested Receiver Audio Frequency Characteristic

Figure 3 shows allowable limits of the audio output in dB at various frequencies referenced to the 1 kHz audio output level into a 600 ohm load for fixed RF deviation of ± 0.5 kHz.

5.4 Miscellaneous

5.4.1 Required Protection Against False Transmission

Failure of any component or combination of components shall not produce a false demand for operation of the mobile transmitter. Additionally, the set must not be capable of transmitting in the on-hook condition, except for the IMTS acknowledge signal, nor should transmission be possible with the set off-hook in the IMTS mode except when the appropriate logic signals have been exchanged as described in Section 7.

5.4.2 Suggested Considerations for Protection of Personnel

The radio equipment shall be designed to protect users and maintenance personnel against electrical hazards, especially those arising from high voltages. This requires providing adequate insulation, locating high-voltage components so as to prevent accidental contacts, and designing circuits at test and metering points to minimize exposed potentials.

5.4.3 Required Full Duplex Operation

The radio equipment shall be capable of operating full duplex (simultaneous transmission and reception) over the frequency channels indicated in Section 3.4

6. INTERFACE SPECIFICATION - MJ MOBILE TELEPHONE SYSTEM - RADIO UNIT

6.1 As indicated in Section 4.3, interface specifications are defined in two categories, that is, "required interface specifications" and "suggested interface specifications." These cover radio frequency and audio frequency characteristics of the radio unit operating with the MJ mobile telephone system.

6.2 Mobile Transmitter

6.2.1 Environmental Requirements See Section 5.2.1

6.2.2 RF Output Power

When switched to each of 11 channels in turn RF power output shall be:

required minimum output: 13 watts minimum per channel

suggested output: at least 20 watts per channel and shall not vary more than ± 1dB except under severe environmental conditions.

suggested maximum output: 30 watts: This upper bound is established to minimize interference to nearby base stations operating on the same channel.

6.2.3 Required Minimum Operating Delay

After an adequate warm-up period the equipment shall deliver at least 70 percent of its full RF output power within 0.05 second after receiving a "transmitter on" command.

6.2.4 Required Tone Sensitivity

The tone input levels (at 1336 Hz, 1633 Hz, and 2150 Hz) shall cause a minimum of ±3.3 kHz deviation of the RF carrier as measured at the antenna jack (see Figure 4 for pre-emphasis response).

6.2.5 Suggested Speech Sensitivity

The maximum sensitivity at the speech input shall be such that the input level at 1000 Hz shall cause ±3.3 kHz deviation of the RF carrier as measured at the antenna jack (see Figure 4 for pre-emphasis response).

6.2.6 Required Modulation Deviation Limiting

See Section 5.2.6

6.2.7 Suggested Audio Distortion Limits

See Section 5.2.7

6.2.8 Modulation Stability

See Section 5.2.8

6.2.9 Suggested Transmitter Audio Frequency Characteristics

Figure 4 shows allowable limits of audio input (below limiting) in dB, referenced to the audio input levels at 1 kHz required to provide ±0.5 kHz deviation.

6.2.10 Required Type of Modulation and Modulation Symmetry

See Section 5.2.10

6.2.11 Suggested Limit of FM Hum and Noise

FM hum and noise modulation an the RF carrier shall be at least 50 dB (with C-message weighting) below the level of a 1000-Hz tone causing ±3.3 kHz deviation.

6.2.12 Suggested Limit of Residual AM Modulation

Same as Section 5.2.12

6.2.13 Suggested Margin of Drive

Same as Section 5.2.13

6.2.14 Harmonic and Spurious Emissions

required specification: in FCC Rules and Regulations

suggested specification: harmonic and spurious emissions falling in the TV bands shall be at least 90 dB below the unmodulated carrier. Any other harmonic and spurious emissions shall be at least 85 dB below unmodulated carrier.

Note: Care should be taken to limit to acceptable levels emissions and spectrum noise falling in the mobile receiver's frequency range.

6.2.15 Spectrum Noise Suppression

required specification: see FCC Rules and Regulations

suggested specification: the RF spectrum noise suppression at 30 kHz and farther away from the carrier frequency shall be at least 67 dB (See Note 6.2.14). This suppression is defined as the difference (B-A) when these quantities are measured as outlined below, using signal generator and companion receiver tuned 30 kHz and farther away from the radio equipment's transmitted carrier frequency. (A) (dBw) = the on-channel signal generator input to the companion receiver required to give 12 dB SINAD ratio in its audio output in the absence of interference from the transmitter. (B) (dBw) = the interfering transmitter carrier signal (unmodulated) at the companion receiver input, when adjusted in level so that its accompanying noise decreases the SINAD ratio in the receiver output to 10 db.

Note: $\text{SINAD} = \frac{\text{signal + noise + distortion}}{\text{noise + distortion}}$

6.2.16 Suggested Intermodulation Conversion Loss

The third order [(2A-B)etc.] conversion loss in the output stage of the equipment shall be at least 6 dB.

6.2.17 Frequency Stability

Required specification: $\pm$0.0005% (in FCC Rules and Regulations)

Suggested specification: carrier frequency determining circuits shall maintain the equipment within $\pm$0.0005 percent of its assigned channel frequency, within 1 minute after the application of primary supply voltage. Oscillator design shall assure that after initial adjustment, the frequency tolerance

of ±5 ppm shall be maintained for at least one year. This is to include ±0.5 ppm for setting capability and ±0.5 ppm allowed for instrument error.

Note: See Note in Section 5.2.17

6.3 Mobile Receiver

6.3.1 Environmental Requirements

See Section 5.2.1

6.3.2 Suggested RF Sensitivity

The equipment shall have receiving sensitivity of at least -140 dBw on all channels, where sensitivity is defined as the RF input at the antenna jack to provide 20 dB quieting of receiver noise output with 3 kHz flat weighting. When switched to each of the 11 channels in turn, the sensitivity shall not vary more than ±0.5dB. In addition, at least 12 dB SINAD shall be produced by -140 dBw (at the antenna jack) modulated by 1 kHz at 3.3 kHz deviation. For extreme environmental conditions, the sensitivity shall not be less than -138 dBw (3kHz flat weighting).

6.3.3 Suggested Limit on Hum and Noise Level

Hum and noise amplitude in the audio output shall be at least 47 dB below the audio output produced by a carrier deviated ±3.3 kHz with a 1 kHz tone using 15 kHz flat weighting.

6.3.4 Suggested Modulation Acceptance Bandwidth

The modulation acceptance or "nose" bandwidth, as measured by the single-frequency limiter-current method at the 6-dB down points, shall be at least 5 kHz on each side of the receiver tuned frequency.

6.3.5 Suggested Selectivity

The selectivity, as measured by the two-frequency method with modulated signals, shall provide at least 85 dB attenuation at 30 kHz away

from the receiver tuned frequency, and at all greater separations.

6.3.6 Suggested Intermodulation Performance

When subjected to an input of two unwanted RF carrier signals at -74 dBw amplitude (-77 dBw under severe environmental conditions), 30 kHz and 60 kHz away from the receiver tuned frequency, the amplitude of the resultant intermodulation product as measured by limiter current shall not exceed -140 dBw. This is an intermodulation conversion loss of 66 dB.

6.3.7 Suggested High Signal Level Intermodulation

The intermodulation conversion loss of the receiver at high input signal levels up to -36 dBw shall be at least 40 dB. The equivalent on channel signal shall be assumed to be the same as the level of on channel signal with standard modulation required to produce 6 dB signal in the presence of the interfering carriers.

6.3.8 Suggested Desensitization

With -140 dBw on channel with standard modulation of 1 kHz deviated ±3.3 kHz and with -60 dBw minimum on either adjacent channel, the SINAD measure shall be at least 10 dB.

6.3.9 Undesired Radiated Power

Required specification: see FCC Rules and Regulations

Suggested specification: any RF signals emitted by the receiver shall not be above 10 microvolts, as measured across a 50-ohm termination connected to the antenna jack.

6.3.10 Suggested Spurious Response Rejection

The spurious response rejection as measured by the single frequency limiter current quieting method* with unmodulated signal shall be 85 dB minimum for (ft+fr)/2 and 2(ft-fr), 90 dB minimum for 18 kHz and all greater separations from the carrier

where ft = transmit frequency and fr = receive frequency.

*Limiter current equivalent of 20 dB quieting with 15 kHz flat weighting.

6.3.11 Required Type of Modulation

The equipment shall be capable of receiving phase modulated RF signals with a maximum deviation of ±5 kHz.

6.3.12 Suggested Receiver Audio Frequency Characteristics

Figure 5 shows allowable limits of the audio output in dB at various frequencies referenced to the 1 kHz audio output level into a 600 ohm load for fixed RF deviation of ±0.5 kHz.

6.4 Miscellaneous

6.4.1 Required Protection Against False Transmission

See Section 5.4.1

6.4.2 Suggested Considerations for Protection of Personnel

See Section 5.4.2

6.4.3 Required Full Duplex Operation

See Section 5.4.3

7. SUPERVISORY UNIT OPERATION - MJ AND MK MOBILE TELEPHONE RADIO SYSTEMS

7.1 The supervisory unit provides the detection and decoding of base-to-mobile signaling, the generation of mobile to base signaling tones and the logic required to control the mobile radio unit. Following is a functional description of mobile telephone calls through the supervisory unit.

7.2 LAND-TO-MOBILE CALL - AUTOMATIC (Figure 6)

7.2.1 The mobile radio, when turned on, hunts over each channel in its complement until the idle tone transmitted from the base station is detected. The presence of idle tone on any one channel causes the mobile to latch to that marked idle channel.. When a call is received at the control terminal, the base station indicates the marked channel busy by replacing idle tone with seize tone. The supervisory unit is activated, it prepares to receive coded calling signals and inhibits the mobile from originating a call.

7.2.2 Shortly after replacing idle tone with seize tone, the base station transmits the calling code (telephone number) of the desired mobile. Each digit of the seven digit code is comprised of alternate 50 msec bursts of idle (2000 Hz) and seize tone (1800 Hz), interrupted by 250 to 5000 millisecond of seize tone between each digit. The number of idle tone bursts corresponds to the digit transmitted. For example, if the code digit to be transmitted is 3, then three bursts of idle tone are sent in the code pulse train. These pulses are counted by each mobile unit and compared with a code preset into the supervisory unit.

7.2.3 If a mobile correctly receives all seven digits of the calling code, the mobile unit's transmitter is turned on and an acknowledge signal is transmitted (750 msec of guard tone 2150 Hz); a "transmitter on" lamp is turned on at the control unit during this interval. (FCC Requirement)

7.2.4 Upon receipt of the acknowledge signal, the base station sends a series of alternate idle and seize tone pulses to actuate the mobile ringer (25 msec alternate idle and seize tones during the 2 seconds of ringing; seize tone only during the 4 seconds of silent interval).

7.2.5 When the handset is removed from its holder (off-hook) to answer an incoming call, the supervisory unit inhibits the search for idle tone, turns on the transmitter and sends 400 msec of connect tone (1633 Hz). While transmission is in progress, a "transmitter on" lamp is turned on at the control unit (FCC requirement). After the transmission of connect tone, the handset is activated and conversation follows.

7.2.6 When the call is completed and the handset is returned to its holder (on-hook), the supervisory unit sends a 750 msec disconnect signal of alternate 25 msec pulses of disconnect (1336 Hz) and guard (2150 Hz) tones.

7.2.7 After the transmission of the disconnect signal the transmitter is deactivated and the mobile unit is unlatched and allowed to hunt for a new marked idle channel. The "transmitter on" lamp is extinguished.

7.2.8 If a wrong number is received for any of the digits in the calling code (area code and station number) and therefore a mismatch has occurred, the mobile is released from the latched channel condition and commences to search for a new marked idle channel.

7.2.9 If a call is left unanswered for about 45 seconds after ringing begins, the base station removes seize tone from the channel. This releases the mobile to hunt for a new marked idle channel.

7.3 MOBILE-TO-LAND CALL AUTOMATIC (FIGURE 7)

7.3.1 When the subscriber goes off-hook to initiate a call, and the mobile is receiving idle tone at the time of off-hook, the following events occur:

- the mobile is inhibited from hunting for a marked idle channel
- the transmitter is turned on (indication at control unit)
- guard tone is sent for 350 msec

7.3.2 If after going off-hook, the mobile fails to receive idle tone for a period of 350 msec (channel seized by another mobile) or continues to receive idle tone for more than 400 msec (mobile transmission of connect tone not received by base station), the call attempt is blocked, the transmitter is turned off, and the control unit "transmitter on" indicator is extinguished.

7.3.3 After 350 msec of guard tone from the mobile, under the condition described in 7.3.1., 50 msec of connect tone is transmitted to the base station; mobile guard tone is turned off during this interval (connect interval) In addition, the mobile is inhibited from blocking the attempted call after idle tone is removed by the base station, within the constraints of 7.3.2.

7.3.4 Upon receipt of connect tone from the mobile, the base station quickly removes idle tone from the channel. After a pause of at least 250 msec (seize delay) it transmits a minimum of 50 msec of seize tone (seize interval). The mobile detects seize tone and prepares to start sending the mobile's identification number (area code and station number). When seize tone is removed by the base station, the mobile starts generating its identification information. Each digit in the seven digit identification code is represented by the sum of pulses of connect tone (1633 Hz). Pulse and interpulse times are 25 milliseconds. Interdigit time is 190 milliseconds. An interdigit pulse occurs after every digit, including the last (seventh) digit. A pulse parity checking scheme is used which requires that an absense of modulation occur between the first and second pulses of the identification code, and that a similar absence of modulation must occur following all odd numbered pulses of the identification code.

Guard tone (2150 Hz) must be transmitted between the second and third pulses of the identification code and must be similarly transmitted following all even numbered pulses of the code. Since the identification code pulse numbering is cumulative through the entire seven digit code (e.g. 205-0551 has 38 pulses) the interdigit pulses (190 msec.) must follow the same parity checking scheme as do the interpulse pulses, with regard to their containing guard tone modulation or not. (E.g. in the number 205-0551, the first, second, fifth, and terminating (seventh) interdigit pulses are modulated with guard tone.)

7.3.5 After the identification code is outpulsed the handset is activated to receive dial tone. When dial tone is received by the mobile, the telephone number of the desired party may be dialed. The dialing action of the control unit is converted into alternate bursts of guard and connect tone. When the dial is off-normal and a set of normally open contacts are closed, the mobile transmits guard tone. When the dial is released, alternate bursts of connect and guard tones are sent as the dial contacts alternately open and close. When the contacts are open, connect tone is transmitted; when the contacts close, guard tone is transmitted. With the dial returned to its resting (normal) position tone is cut-off.

7.3.6 When the mobile telephone subscriber goes on-hook, the mobile generates alternate 25 msec bursts of disconnect and guard tone for 750 msec. The transmitter and "transmitter on" indication are then turned off and the mobile commences to search for a marked idle channel. If idle tone is detected by the mobile, it locks on that channel and the search action is stopped.

7.3.7 As indicated previously, the MJ type mobiles can operate in the manual mode when traveling into manual service areas. The need of this option depends on the extent of dial service in the region traveled by the customer.

7.4 BASE-TO-MOBILE - MANUAL - 150 MHz, MJ SYSTEM ONLY

7.4.1 When the manual mode of operation is selected at the control unit, the tone detectors of the automatic mode are retuned to 1500 Hz and 600 Hz respectively. In addition, oscillators and control circuits are

inhibited so that in effect the automatic mode of operation and marked idle channel hunting are bypassed. When a mobile is called, the base station transmits its calling code. The code consists of the seven digits of the IMTS identification code transmitted by sending groups of alternate 600-and 1500-Hz tones modulating the RF carrier. In the supervisory unit, each frequency shift from 600 to 1500 to 600 Hz produces a pulse. These pulses are counted and compared with the code preset into the supervisory unit; this code must be the same code used in the automatic mode. When the proper code is received, the ringer in the control unit is turned on and ringing occurs continuously until the time of off-hook, or until a reset pulse in transmitted by the operator at the switchboard.

7.4.2 When the handset is taken off-hook, it becomes activated. The push-to-talk button on the handset should be however, momentarily inhibited. This prevents the transmitter from being accidentally keyed if the push-to-talk button is depressed while going off-hook. After elapse of the momentary delay period, when the push-to-talk button is pressed, the transmitter and "transmitter on" indicator are turned on, permitting conversation. Push-to-talk buttons are unnecessary on 450MHz, MK System handsets.

7.4.3 If the wrong number is received for any of the code digits the ringer is prevented from being activated.

7.5 MOBILE-TO-BASE MANUAL

7.5.1 When the handset is removed from its holder (off-hook) the transmitter and "transmit on" indicator are keyed by the push-to-talk button as described previously. After contacting the operator at the switchboard and being connected to the called party, conversation may begin.

7.6 PROTECTION AGAINST FALSE TRANSMISSION

7.6.1 In any situation other than those specifically described above, the mobile transmitter shall be inhibited from operating.

8. INTERFACE SPECIFICATIONS - MJ AND MK MOBILE TELEPHONE SYSTEMS - SUPERVISORY UNIT

8.1 Environmental Requirements

See Section 5.2.1.

8.2 AUTOMATIC MODE

The following supervisory unit interface specifications requirements shall be met for proper operation on an MJ or MK system.

8.2.1 Suggested Channel Interrogation Time

When the receiver is commanded to search for a marked idle channel in normal operation with transmitter off, the mobile shall switch to each channel in sequence and stay on each channel so selected (fixed channel combination selection in Home mode, pushbutton channel combination selection in Roam mode) for a duration of 250 $\pm$ 75 msecs.

8.2.2 Suggested Maximum Channel Hunt Time

The maximum time required to reach a marked idle channel is defined as that time required to search 10 channels. This is a maximum of 3.25 secs.

8.2.3 Suggested Maximum Dwell Time on Skipped Channel

If channel switching is sequential, the maximum dwell time suggested for a channel not selected is 4 msecs.

8.2.4 Required Stand-by Characteristics:

- Radio transmitter-off
- Supervisory unit searching for marked idle channel (IMTS modes)
- Muted speech input to transmitter
- Busy indication at control unit-off
- Handset receiver and ringer at control unit deactivated and receiver audio output open
- No tone inputs to transmitter
- No dial pulse inputs to supervisory unit

8.2.4.1 Required Blocking of Switchhook in Standby

When the handset is taken off-hook (at control unit) a busy indication shall be given, all other conditions remaining on standby.

8.2.5 Marked Idle Characteristics

Idle tone applied to supervisory unit from receiver output.

8.2.5.1 Required Maximum Idle Tone Acceptance Bandwidth

The maximum idle tone acceptance bandwidth shall be no more than that required to provide efficient signaling performance with the pulse-interpulse timings specified in 8.2.11.5.

8.2.5.2 Suggested Minimum Idle Tone Acceptance Bandwidth

With any tone within 2000 $\pm$ 12 Hz applied to the supervisory unit, it shall go the "stop search" condition within 160 msec but no sooner than 80 msec after application of idle tone to the unit.

8.2.5.3 Required Rejection of False Idle Tones

The unit shall continue searching for a marked idle channel (standby condition) in the presence of false idle tones of the following characteristic:

idle tone present for 80 msec to less than time used in 8.2.5.2 for "stop search" - idle tone not present for a maximum of 100 msec. idle tone present for 80 msec to less than time used in 8.2.5.2 for "stop search" - and so on.

8.2.5.4 Required Search After Channel Seizure by Another Mobile

After receipt of idle tone long enough to stop channel searching the mobile shall return to the search condition (standby) within a 100 to 250 millisecond period after idle tone is removed. Seize tone is applied 250 (+10-0) milliseconds after removal of idle tone.

8.2.5.5 Suggested Holding on Fading Idle Channel

After receipt of idle tone long enough to stop channel searching, the mobile shall hold this condition in the presence of fading idle tone exhibiting the characteristics shown below. All other conditions "standby".

idle tone present long enough to stop search - idle tone not present for 80 msec to less than the time used in 8.2.5.4 for "start search" - idle tone present 160 msec (maximum) - idle tone not present for 80 msec to less than the time used in 8.2.5.4 for "stop search" - and so on.

8.2.6 Connect Characteristics

These characteristics are as follows:

8.2.6.1 Required Connect Delay

The connect delay is defined as the interval between the time the transmitter is commanded to turn on in response to an off-hook condition (see MJ and MK transmitter operating delay requirement) and the leading edge of the connect tone (1633 Hz) pulse applied to the input of the transmitter. During the connect delay, the mobile transmits guard tone (2150 Hz) and is locked on a marked idle channel. The connect delay shall be nominally 350 msec. (extreme limits 250 to 700 msec)

8.2.6.2 Required Connect Interval

The connect interval is defined as the duration of the connect tone (1633 Hz) applied to the transmitter input after a connect delay as defined in 8.2.6.1. The connect interval (time between the leading and trailing edges of the connect tone burst) shall be 50 $\pm$ 13 msec.

8.2.6.3 Required Guard Tone Before and After Connect Burst

The unit shall transmit guard tone (2150 Hz) not only before the connect burst (i.e., during connect delay) but also after the connect burst.

8.2.6.4 Required Connect Attempt Blocked by Prior Channel Seizure by Another Mobile

The mobile unit shall not transmit a connect tone burst if idle tone is removed from the base station (channel seized by another mobile) during the connect delay interval. Instead it shall give a busy indication

at the control unit (section 8.2.4.1) (if such indication is provided) and shall go to "stand by" on all other conditions as shown in 8.2.4 until handset is placed in the on-hook condition.

8.2.6.5 Required Connect Failure from Absence of Channel Seizure Response

The mobile unit shall return to "stand by" if the base station has not removed idle tone at the conclusion of the connect interval. A busy indication shall be given to the control unit (if such indication is provided) (only condition not on "stand by" see 8.2.4).

8.2.7 Required Automatic Number Identification (ANI) Characteristics

For the mobile to identify itself, it must first be successfully past the connect interval. (see mobile to land call description in 7.3).

8.2.7.1 Start of ANI Pulsing:

The mobile unit shall commence sending its ANI code within 100 to 300 milliseconds (ANI delay - 250 milliseconds nominal) after the removal of a pulse of seize tone (1800 Hz) lasting 50 to 7000 msec.

8.2.7.2 Required No ANI on Fades of Seize Tones

With the mobile successfully past the connect interval and transmitting guard tone (2150 Hz), the mobile shall not start identification in the presence of fading seize tone from the base station of the following charactertics: seize tone present - seize tone not present for 80 msec to the time used in 8.2.7.1 for "ANI Delay" - and so on.

8.2.7.3 Required ANI Pulse, Interpulse, Interdigit Timing

Each pulse of a code shall be represented by a pulse of connect tone (1633 Hz). Pulse and interpulse times shall be 25±5 msec. Interdigit times shall be 190 msec. (extreme limits 130 to 280 msec) See section 7.3.4 for description of the ANI sequence.

8.2.7.4 Required Guard Tone Parity

Guard tone (2150 Hz) must be absent between the first and second pulses of an ANI code, and must be similarly absent following all subsequent odd-numbered pulses of the code. Guard tone must be present between the second and third pulses of an ANI code, and must be similarly

present following all subsequent even-numbered pulses of the code. For example, 205-0551, contains an even total number (38) of pulses, guard tone must be present following the last (seventh) digit. For this code (or any other code with an even total number of pulses) guard tone must be on for 190 msec. following the last digit in order to satisfy guard tone parity requirements at the control terminal. See 7.3.4 for an in depth description.

8.2.7.5 Required Dial Inhibited During ANI

If the dial is operated during transmission of the ANI code, the unit shall transmit the proper ANI code just as if the dial inputs were in the normal condition.

8.2.8 Required Audio State Characteristics (Mobile-to-land)

With the mobile unit successfully past ANI, there shall be no tones put to the input of the transmitter and the mobile shall be in the following conditions:

- Transmitter on (also indication of it at the control unit)
- Busy indication at control unit not activated (if provided)
- Speech input to transmitter activated.
- Receiver audio output enabled, handset receiver activated, ringer de-activated.
- Supervisory unit not searching for marked idle channel

8.2.9 Dialing Characteristics

With the mobile in the audio state (8.2.8), the mobile shall meet the following requirements on dialing:

8.2.9.1 Required Handset Muted with Dial Off-Normal

With the dial off-normal, the speech input to the transmitter shall be muted, dial signaling tones (see 7.3.5, 8.2.9.1, and 8.2.9.2) are impressed upon the transmitter input, the receiver and audio output shall be open and the headset muted. All other mobile conditions as in 8.2.8.

8.2.9.2 Required Guard Tone During Dialing

With the dial off-normal and the pulse oontacts closed, the mobile must provide guard tone (2150 Hz).

8.2.9.3 Required Connect Tone During Dialing

With the dial off-normal and the pulse contacts open the mobile must provide connect tone (1633 Hz).

8.2.9.4 Required Dial Speed:

Dials used in the IMTS services shall maintain a pulsing speed of between 8 and 11 pulses per second throughout the range of dial rundown in the environment specified in 5.2.1.

8.2.9.5 Required Dial Percent Break:

Dials used in the IMTS services shall maintain a 58 to 64 percent break pulsing range throughout the rundown of the dial in the environment specified in 5.2.1.

8.2.10 Required Disconnect Characteristics (Mobile-to-land)

Whenever the mobile has made a successful connect attempt, any subsequent return to on-hook must cause the transmission of a disconnect signal, in complete accordance with the following requirements.

8.2.10.1 Required Condition of Mobile During Disconnect Signal

During the disconnect burst with the control unit handset on-hook the mobile shall be in the following condition:

- Transmitter-on (indication at control unit-on)
- Busy indication at control unit not activated
- Speech input to the transmitter muted
- Receiver audio output open, handset receiver and ringer deactivated
- Mobile not searching for marked idle channel

8.2.10.2 Required Disconnect Signal

During the disconnect interval, the mobile must produce a signal sequence consisting of alternating bursts of disconnect (1336 Hz) and guard (2150 Hz) tones at the transmitter signal input. The duration of each burst must be 25 $\pm$ 5 msec.

8.2.10.3 Required Disconnect Signal Time Interval

The duration of the disconnect signal shall be 750 $\pm$ 250 msec.

8.2.10.4 Required Blocking of Switchhook During Disconnect

During the disconnect Signal, and going from an on-hook to and off-hook condition, the unit shall provide a busy indication at the control unit with all other conditions on standby (8.2.4) as modified by the disconnect signal conditions (8.2.10.1). The disconnect signal shall be in accordance with 8.2.10.2 and 8.2.10.3 just as if the mobile was still on-hook.

8.2.10.5 Required Return to Standby After Disconnect Signal

Upon termination of the disconnect signal, the unit shall return to standby (8.2.4).

8.2.11 Required Decoding Characteristics

Except as otherwise specified, the mobile shall be in the standby condition (8.2.4).

8.2.11.1 Required Maximum Seize Tone Acceptance Bandwidth

The maximum seize tone acceptance bandwidth shall be no more than that required to provide efficient signaling performance with the pulse-interpulse timings specified in 8.2.11.6.

8.2.11.2 Required Minimum Seize Tone Acceptance Bandwidth

With the mobile locked on a marked idle channel (2000 Hz) Idle Tone modulation) the mobile shall remain locked (stop search condition) when any tone within 1800 $\pm$ 12 Hz seize tone is applied simultaneously with the removal of idle tone.

8.2.11.3 Required Blocking of Switchhook from Seize Tone

With the mobile unit locked on a marked idle channel, the mobile shall remain in the "stop search" mode when idle tone (2000 Hz) is changed to seize tone (1800 Hz). With the seize tone present and the "stop search" mode remaining commanded, a busy indication shall be given at the control unit when the handset is taken off-hook (removed from its holder). All other conditions shall be on standby (8.2.4).

8.2.11.4 Commencement of Channel Search:

With the mobile unit in the "stop search" condition per 8.2.11.2, seize tone is removed and no modulation is provided, the mobile unit shall commence channel searching after a delay of 100 to 300 msec. (250 msec nominal).

8.2.11.5 Hold on Fading Seized Channel

With the mobile locked on a seized channel per 8.2.11.2, the mobile shall

remain locked on that channel in the presence of a fading seize tone of the following characteristic:

- seize tone present for 160 msec (maximum) - seize tone not present for 80 msec up to the time used in 8.2.11.4 for commencing search.
- seize tone present 160 msec (maximum) - seize tone not present for 80 msec up to the time used in 8.2.11.4 for commencing search and so on.

8.2.11.6 Required Speed Range of Matching Coding

The mobile shall successfully decode an identification code pulse train, with the pulse and interpulse range given below. Successful decoding is defined as acknowledgment of the code, in accordance with 8.2.12.

Pulse - Interpulse and Interdigit Limits (from base station)

Pulse Time: 20 to 80 msec (50 msec nominal) of idle tone

Interpulse Time: 20 to 80 msec (50 msec nominal) of seize tone

Interdigit Time: 250 msec to 5 sec (300 msec nominal)

8.2.11.7 Suggested Return to Standby on Mismatch Code

With any input code other than the mobile's, the mobile shall return to standby promptly after the first digit in the pulse train is received which does not match the mobile's code. The mobile must not acknowledge these codes in any way except to return to standby.

8.2.12 Acknowledgement and Ringing Characteristics

With a matching code input, the mobile shall acknowledge receipt of code and provide ringing, as described below.

8.2.12.1 Required Acknowledgment Signal

Upon receipt of the matching code, the unit shall turn on the transmitter and provide the acknowledge signal for approximately 750 msec. The acknowledgment signal appears at the transmitter signal input and and is guard tone (2150 Hz).

8.2.12.2 Required Blocking of Switchhook During Acknowledgment Burst

During the acknowledgment burst, if the control unit is placed in the off-hook condition, a busy indication (if provided) shall be provided at the control unit. The mobile shall provide the acknowledgment burst and subsequent functions as if the control unit was on-hook.

8.2.12.3 Required Ringing

After the acknowledgment burst, the base station control terminal will furnish ringing to the control unit with a one to two (1-2) second on, three to four (3-4) second off duty cycle. Ringing pulses from the base station are alternate 25- msec pulses of idle tone (2000 Hz) and seize tone (1800 Hz). Seize tone alone is applied during the "off" interval.

8.2.13 Required Answer Characteristics

After acknowledgment of a correct code, with seize tone input holding the unit in the code-recieved condition and with the control unit then placed in the off-hook condition, the unit shall send an answer signal in accordance with the following requirements.

8.2.13.1 Required Answer Interval

The answer interval is defined as the interval between the time the transmitter is commanded to turn on (see transmitter operated delay in 5.2.3) in response to an off-hook condition at the control unit and the end of the answer tone burst produced at the transmitter signal input. The answer interval shall be 400 msec. (extreme limits 287 to 763 msec)

8.2.13.2 Required Answer Tone Code

The mobile unit shall transmit connect tone (1633 Hz) for the duration of the answer interval.

8.2.14 Required Audio Characteristics (Land to Mobile)

After the answer interval, with the control unit off-hook, the mobile shall exhibit the audio characteristics in accordance with all requirements in 8.2.8.

8.2.15 Required Disconnect Characteristics (Land-to-mobile)

After the answer interval, the unit shall exhibit the disconnect characteristics, in response to creation of an on-hook condition at the control unit, in accordance with all requirements in 8.2.10.

8.3 MANUAL MODE OPTION - MJ SYSTEMS ONLY

8.3.1 Manual Standby Characteristics

- Control unit placed in manual mode, no dial pulses from control unit
- Transmitter-off
- Busy indication at control unit-off
- Muted speech input to transmitter
- Handset receiver and ringer at control unit deactivated and receiver audio output open
- Supervisory unit not searching for marked idle channel
- No tone inputs to transmitter

8.3.2 Manual Outpulsing Characteristics

With mobile in manual mode and in standby condition (8.3.1), the following requirements shall be met.

8.3.2.1 Suggested Maximum 1500 Hz Acceptance Bandwidth

The maximum 1500 Hz acceptance bandwidth shall be no more than that required by 1500/600 signaling speed considerations

8.3.2.2 Required Minimum 1500 Hz Acceptance Bandwidth

With any tone within 1500 $\pm$ 12 Hz, the mobile will decode when the inband tones are used to signal the mobile (10 pulses per second transitional along with 600 cps.

8.3.2.3 Suggested Maximum 600 Hz Acceptance Bandwidth

The maximum 600 Hz acceptance bandwidth shall be no more than that required by 1500/600 Hz signaling speed consideration.

8.3.2.3 Required Minimum 600 Hz Acceptance Bandwidth

With any tone within 600 ± 12 Hz, the mobile will decode when the inband tones are used to signal the mobile, along with 1500 Hz.

8.3.2.4 Required Pulsing Speed

The unit shall be capable of decoding 600/1500 Hz transitional signaling at rates of from 8 to 23 pulses per second.

8.3.2.5 Required Ringing

With the correct mobile's IMTS identification code applied to the mobile, the mobile shall energize the ringer until the mobile is reset by (a) the base station by "1" pulse, or (b) off-hook condition at control unit.

8.3.2.6 Required Seven Digit Identification Code:

The code (telephone number) used for receiving calls in the manual mode must be the same as the seven digit code used in the IMTS mode. Use of other than the IMTS telephone number code is unacceptable.

8.3.3 Required Manual Audio Characteristics

With the mobile in an off-hook condition (handset removed from its holder), the mobile shall be in the following condition.

- Transmitter and "Transmitter on" indication under control of the push to talk key.
- Busy indication on control unit-off
- Speech input to transmitter not muted
- Receiver audio output enabled handset receiver activated, ringer deactivated
- Supervisory unit not searching for marked idle channel

8.3.3.1 Required Push-To-Talk Operation

With the mobile in the off-hook condition as in 8.3.3, operation of the push to talk key shall provide transmitter keying. If operation of the push to talk key occurs during the on-hook condition and remains so after the mobile is placed in the off-hook condition there shall be no transmitter keying and a busy indication shall be given (if provided) at the control unit. Subsequent release of the push-to-talk key shall clear the busy indication and allow normal operation as indicated above. With the push-to-talk key

operated, a change from manual to automatic mode (operation of home push-button) shall cause the mobile to provide a busy indication at the control unit while all other conditions shall revert to standby as in 8.3.1.

8.4 EXTREME LIMITS SUMMARY (AUTOMATIC MODE)

Taking into account all component aging allowances and environmental extremes, the mobile shall be capable of functioning under the following parameter limits:

PARAMETER	Min	Nominal	Max
Connect Delay	250 msec	350 msec	700 msec
Connect Interval	37 msec	50 msec	63 msec
Answer Interval	287 msec	400 msec	763 msec
ANI Pulse Time	20 msec	25 msec	30 msec
Interpulse Time	20 msec	25 msec	30 msec
Interdigit Time	130 msec	190 msec	280 msec
Last Parity Bit	130 msec	190 msec	280 msec
Disconnect Interval	500 msec	750 msec	1000 msec
Disconnect Pulses	20 msec	25 msec	30 msec
Acknowledge Interval	500 msec	750 msec	1000 msec
Idle Tone to Stop Search	80 msec		160 msec
Hold on Fade of Idle Tone	100 msec		250 msec
Hold on Fade of Seize Tone	100 msec		300 msec
Connect Frequency	1623 Hz	1633 Hz	1643 Hz
Disconnect Frequency	1328 Hz	1336 Hz	1344 Hz
Guard Frequency	2138 Hz	2150 Hz	2162 Hz
Idle Tone Frequency	1990 Hz	2000 Hz	2010 Hz
Seize Tone Frequency	1788 Hz	1800 Hz	1812 Hz
Outpulsing Speed (From Base)	See 8.2.11.5		
Interdigit Time	250 msec		5 sec

9. TONE ADDRESSING OVER MJ AND MK MOBILE TELEPHONE RADIO SYSTEMS

9.1 Tone addressing signals (similar to Bell System TOUCHTONE®) will not be used in MJ and MK Mobile Telephone Systems due to implications involving national compatibility of roaming customers' dialing calls into non-TOUCHTONE® equipped base station facilities, and FCC regulations regarding uses of tone addressing over DPLMRS facilities for purposes other than placing telephone calls.

9.2 Customer control and radio unit facilities may be provided which contain pushbutton dialing to IMTS dial pulsing converters. Dial pulsing from these converters must meet the dialing requirements of 8.2.9 et. seq.

APPENDIX A

WHERE TO OBTAIN BELL SYSTEM TECHNICAL REFERENCES

These Technical References may be purchased by writing to:

American Telephone and Telegraph Company
Supervisor - Information Center
Room 208
195 Broadway
New York City, New York 10007

All orders should indicate the Technical Reference(s) desired by catalog number and quantity. For example, this particular Technical Reference would be indicated on the order as follows:

(Quantity) - Technical References - PUB 43301

A catalog of Technical References (PUB 40000) is published quarterly listing all current Bell System Technical References. Included in each Technical Reference listing is the title, a synopsis and an ordering number (PUB 4XXXX). In addition, ordering information is given for one-time or standing orders.

(Rev. 3/73)

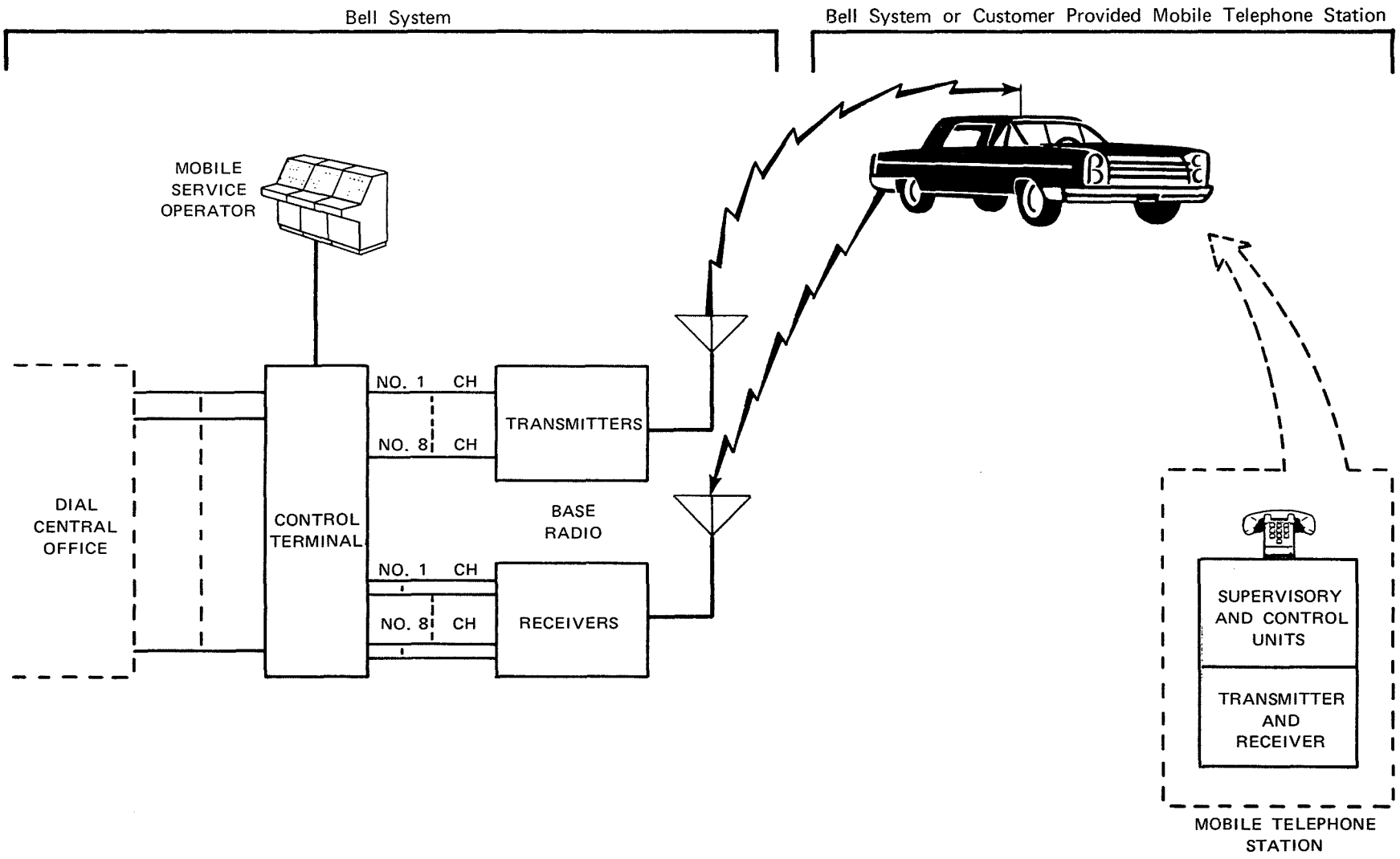


FIGURE 1
MAJOR ELEMENTS OF THE MJ AND MK MOBILE TELEPHONE RADIO SYSTEMS

FIG. 2
MK TRANSMITTER AUDIO FREQUENCY RESPONSE LIMITS

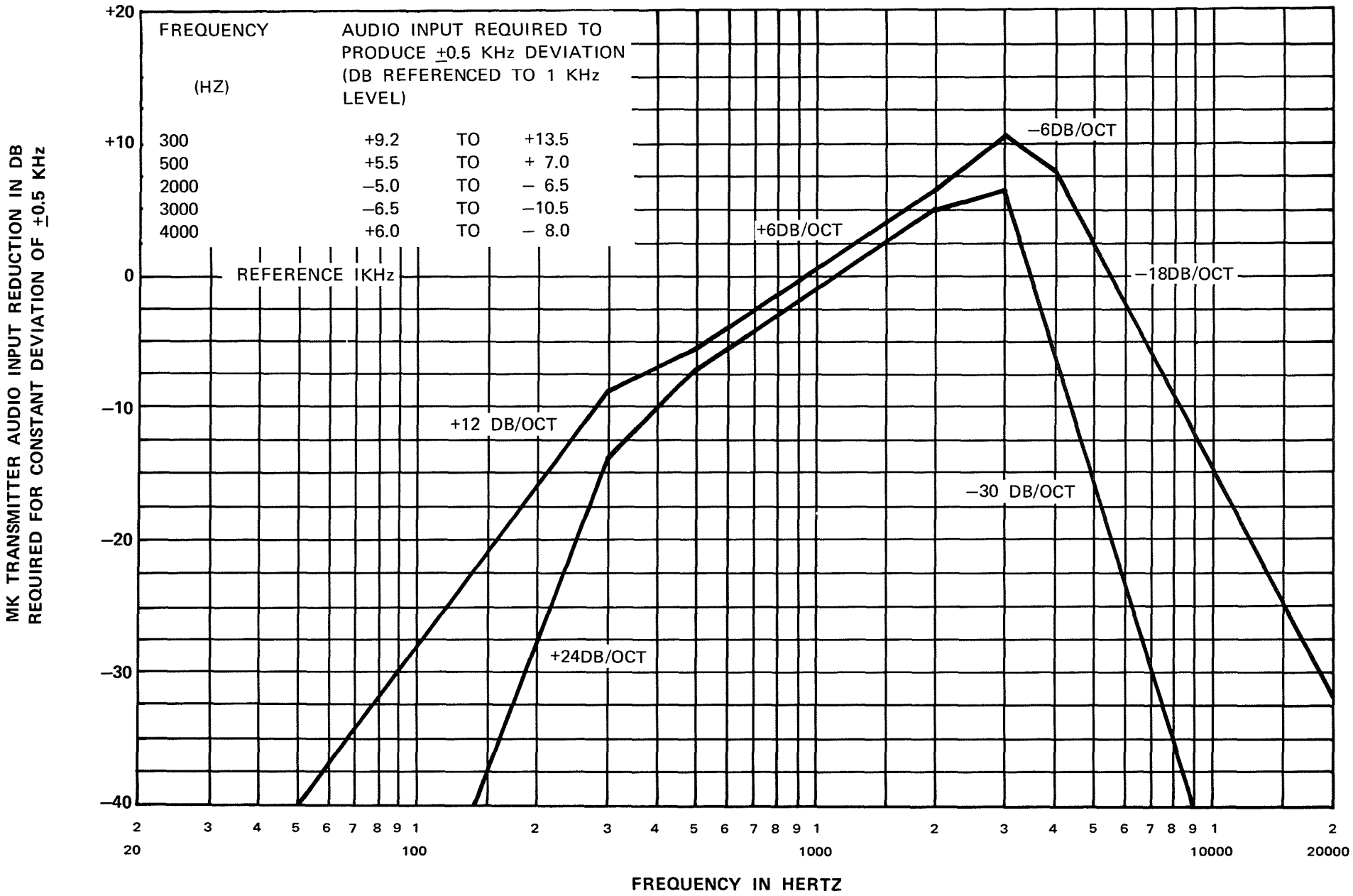


FIG. 3
MK RECEIVER AUDIO FREQUENCY RESPONSE LIMITS

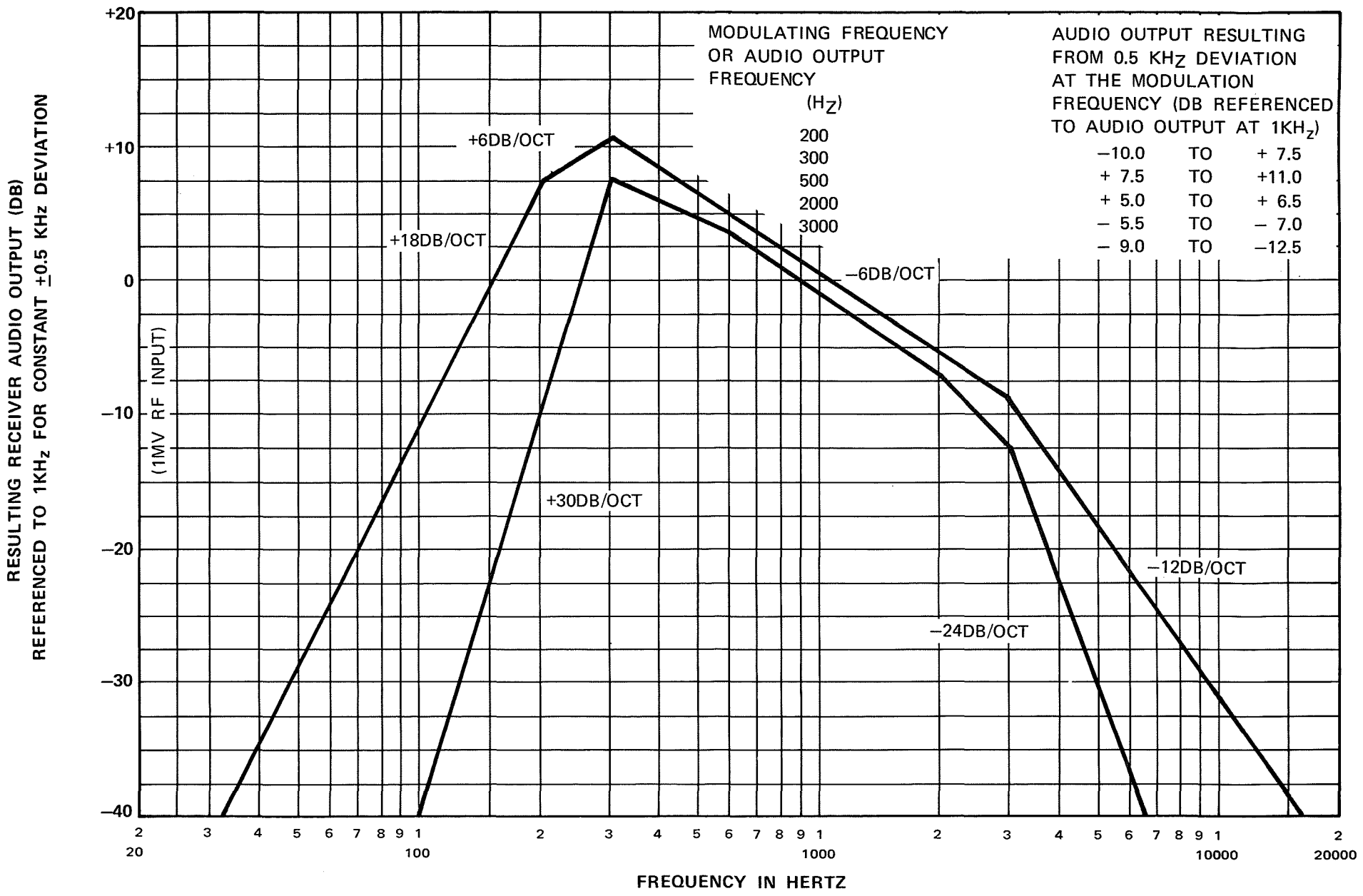


FIG. 4
UPPER AND LOWER LIMIT CURVES FOR RADIO
MJ TRANSMITTER AUDIO FREQUENCY RESPONSE

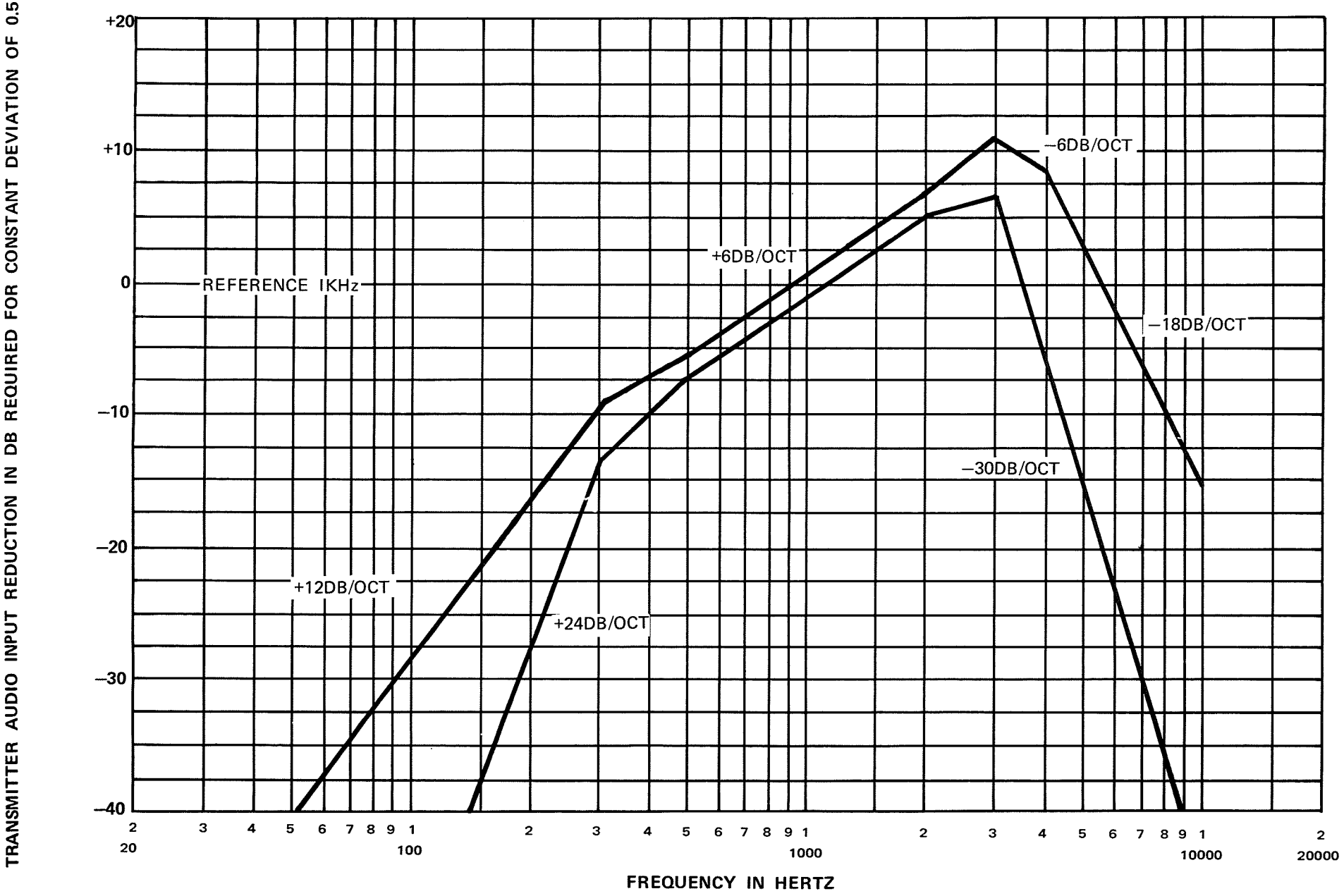
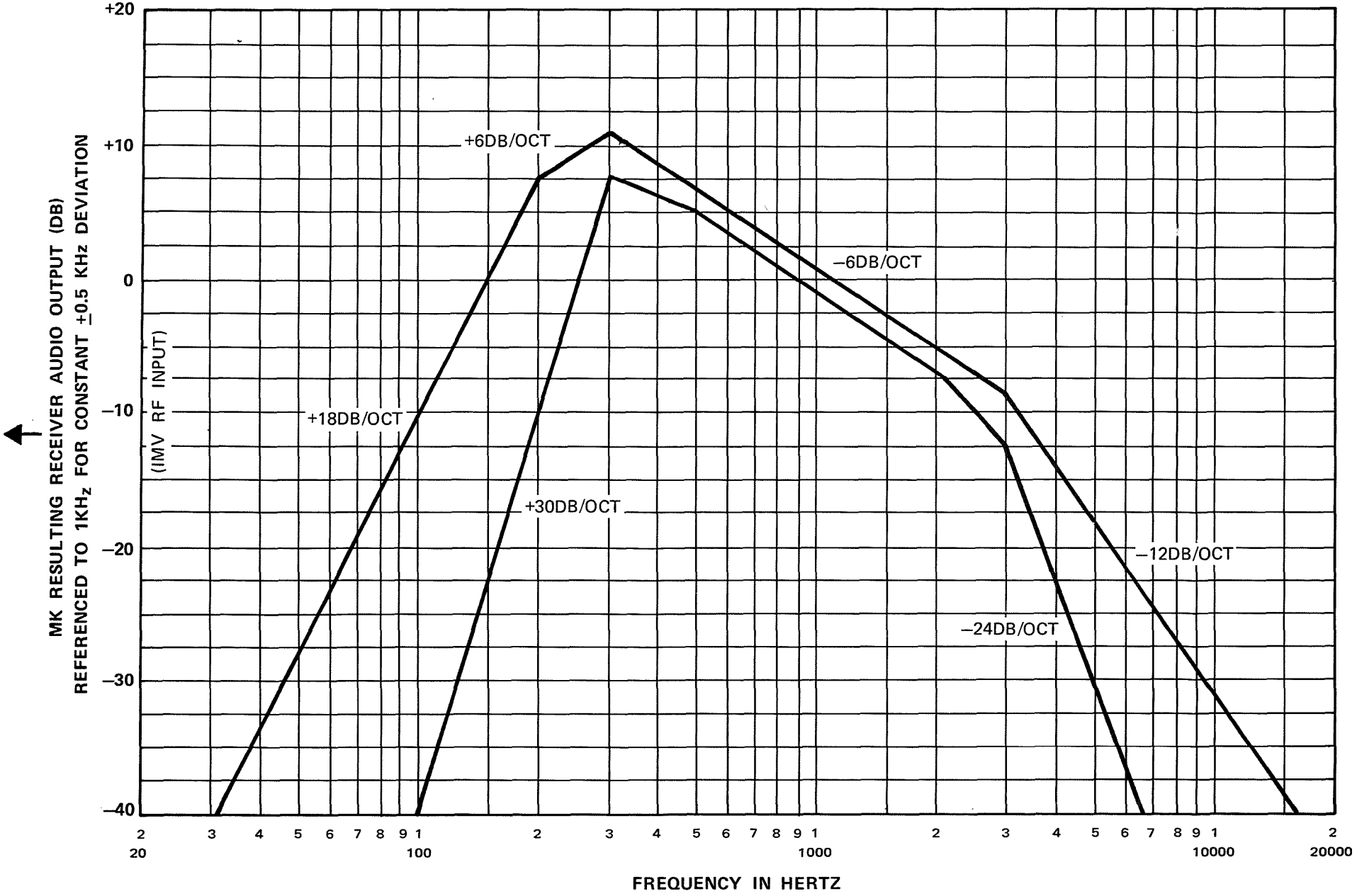


FIG. 5
UPPER AND LOWER LIMIT CURVES FOR RADIO
MJ RECEIVER AUDIO FREQUENCY RESPONSE



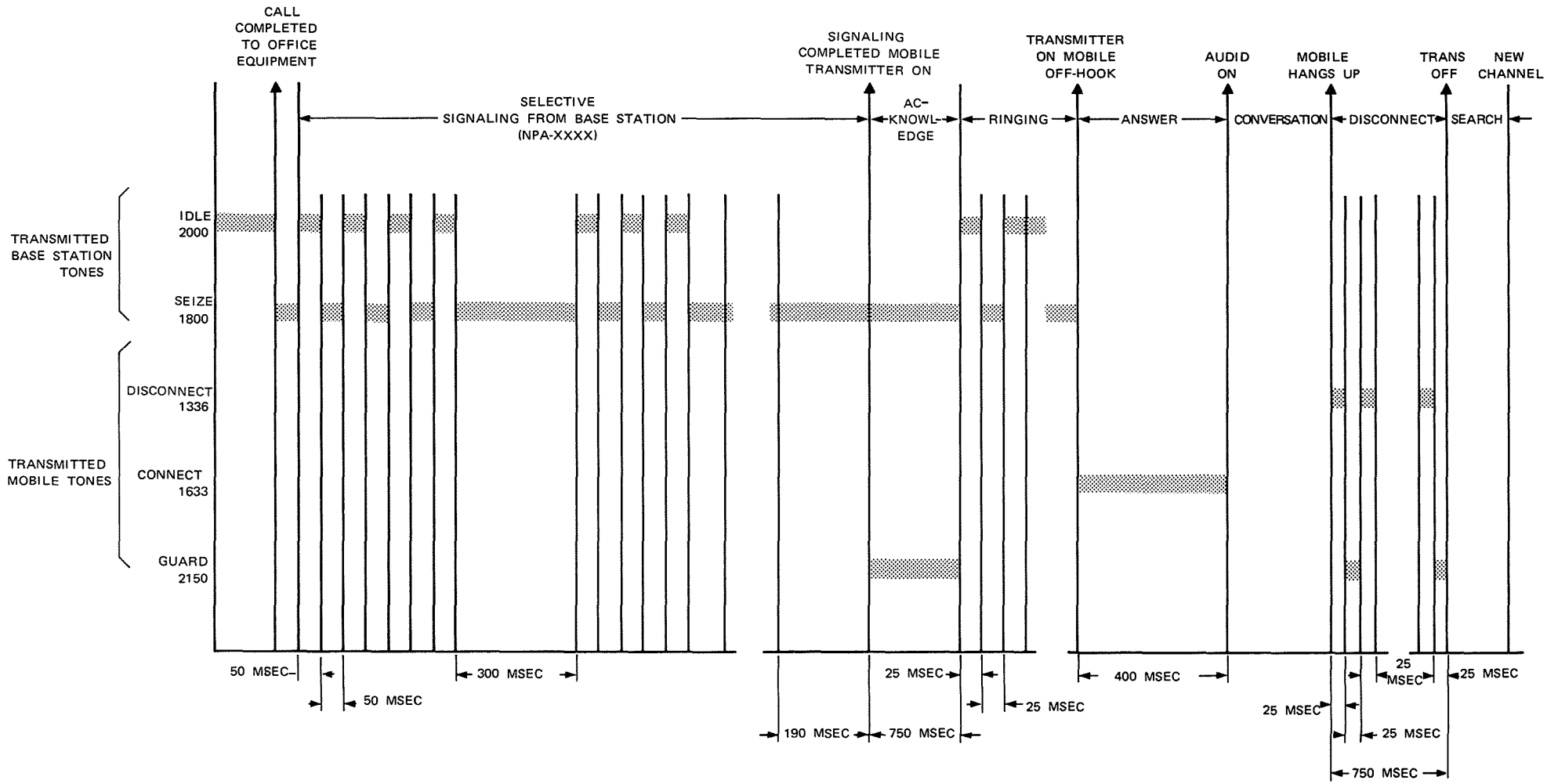
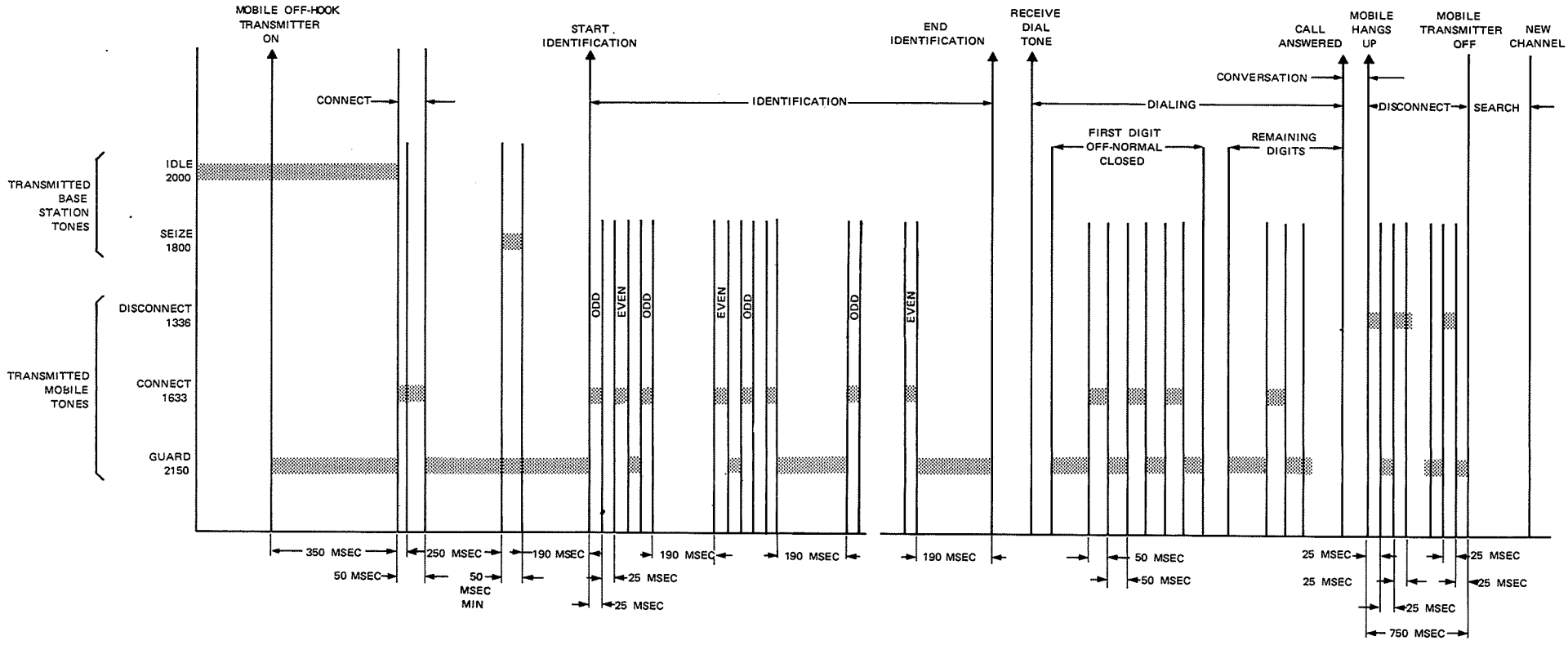


FIG. 6
LAND-TO-MOBILE CALL
SIGNALING TONES SEQUENCE CHART



(Corr. 5-74)

FIG. 7
MOBILE-TO-LAND CALL
SIGNALING TONES SEQUENCE CHART