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Advanced Mobile Phone Service:

A Service Test Mobile Telephone Control Unit

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Guidelines for the design of a mobile telephone control unit have been determined, based on considerations of driving behavior, customer preference, automobile environment, and calling procedure. This paper explains these guidelines and illustrates their application in the design of a service test control unit.

I. INTRODUCTION

The control unit in the Advanced Mobile Phone Service (AMPS) gives people in a moving vehicle access to mobile telecommunications service in much the way a telephone serves people in homes and offices. However, formulating control unit design guidelines for the AMPS involved meeting two challenges not encountered in land-line telephone experience. First, the vehicular nature of this telephone service requires that the control unit have negligible effect on driving behavior, satisfy the preferences of potential subscribers for small, unobtrusive units that are easy to use while driving, and conform to the automobile's environmental constraints.

Second, the AMPS signaling plan uses preorigination dialing to reduce the holding time for the radio channel. With preorigination dialing, call-setup functions normally performed in the switching office are incorporated in the mobile unit where they are controlled by the user.

Consequently, driving behavior, customer preference, automobile environment, and calling procedures were studied to establish design guidelines for control units for use during the developmental system trial[1] and beyond. This paper describes the principal findings from these studies and illustrates their application in the design of a control unit for the service test phase of the trial. The mobile subscriber set for the equipment test phase is described in Ref. 2.

II. DRIVING BEHAVIOR STUDIES

Behavior studies were conducted to investigate the effect of mobile telephone usage on driving. The studies began by looking at the additional activities that people commonly engage in while driving. Such activities include talking with passengers, adjusting the car's air conditioner or radio, and getting change to pay tolls. Although these activities cause some distraction, the studies show that drivers necessarily give priority to driving demands and adopt strategies to minimize the effects of secondary activities on driving behavior. For example, drivers delay in undertaking secondary activities until peak demands of the driving task, such as passing a car or turning a corner, are successfully completed. Drivers also interrupt the secondary activity when driving conditions demand attention, thereby performing the secondary activity at a slower pace.

The use of a mobile telephone is similar to the secondary activities described above. It is therefore reasonable to expect that drivers will employ strategies, such as pausing to review the driving environment after dialing every one or two digits, in order to minimize the effect of the telephone activities on driving behavior. The driving studies confirm this reasoning and show that drivers maintain the same level of driving control when performing mobile telephone activities, including call origination, as when performing other commonly accepted secondary activities such as adjusting a car radio to a specific station.

These studies also reveal that drivers can accommodate a wide range of control unit mounting positions. However, for ease of use they prefer controls that are mounted near the top of the instrument panel and to the right of the steering wheel.

III. CUSTOMER PREFERENCE

Potential AMPS subscribers view overall ease of use as an important consideration in choosing control units. The design direction provided by AT&T on the basis of research into customer preference shows that subscribers want units that are easy to use while driving and blend with the automobile environment. These preferences directly affect the mounting location and the design of the controls, primarily the dial and handset for the control unit.

Subscribers feel more comfortable with control units that minimize the need to divert their eyes or alter their body positions in order to place or receive telephone calls. This suggests mounting the control unit near the top of the vehicle's instrument panel. Subscribers also desire relatively small, unobtrusive units that do not restrict access to vehicle controls or seating areas, nor affect the driver's view of the road ahead. Ideally, the control unit should be built into the instrument panel as are the car radio and air conditioning controls.

For overall ease of dialing, subscribers prefer a pushbutton dial with buttons having approximately the same size and spacing as those found on telephone sets equipped for *TOUCH-TONE®* calling.

Lightweight handsets that are comfortable to hold and easy to cradle on the shoulder are preferred. Full-size handsets (e.g., the Western Electric K-type) meet these needs especially well. Potential subscribers find short handsets and those with a flat cross section to be less desirable.

IV. AUTOMOBILE ENVIRONMENT

The automobile environment has mounting constraints as well as temperature, illumination, and noise levels not normally encountered in setting design objectives for telephone sets intended for use in office and residential environments.

4.1 Mounting constraints

While users would prefer that the control unit be built into the instrument panel, this is not now likely because tightly spaced controls, indicators, and optional devices such as radios and clocks cover most of the usable space within reach of the driver. Changes in the instrument panel which auto manufacturers introduce from year to year and the considerable variations existing between car models compound the problem. While no area close to the driver can be considered as reserved for the control unit, mounting locations are available which vary from car to car. A flexible, adaptive approach to mounting is required to position the control unit in locations acceptable to the driver.

4.2 Temperature levels

Control units mounted in front of or below the instrument panel should be designed to survive ambient temperatures as high as 85° Celsius.[3] Traditional plastic housings and handsets normally used for telephone sets do not perform well at this temperature; thus, high temperature materials, such as polycarbonate plastic, should be used for the control unit. The top surface of the instrument panel is a desirable location for the control unit because it is easily seen and reached by the driver; however, temperatures at this location can reach 113° Celsius[3] and, therefore, present a significant design challenge.

4.3 Illumination levels

The high illumination level of direct sunlight makes the use of light-emitting diode and incandescent indicators on the control unit especially difficult unless they are properly shielded. During night opera-

tion, on the other hand, the illumination level of the controls and visual indicators must not overwhelm the driver whose vision has adapted to night conditions.

4.4 Noise levels

Measurements made in the interior of intermediate-size automobiles show a surprisingly high ambient noise level, even when all windows are closed. At 55 mph on a smooth road, we observed ambient noise levels of about 70 dBA;* this is roughly the same level found in a busy secretarial office with telephones and typewriters in use. At 20 mph, the ambient noise level decreases to about 60 dBA. With the automobile parked in a quiet location and with the engine off, the interior noise level drops to about 40 dBA, the level observed in a quiet room. This wide variation in ambient noise level suggests that user-adjustable level controls are needed for the receive-audio signal, especially if a loudspeaker is used. The relatively high noise levels must also be considered in setting design objectives for the alerting signal level.

V. CALLING PROCEDURES

The AMPS signaling plan uses preorigination dialing to reduce the holding time for the radio channel. To place a call, the user dials a telephone number into a storage register within the mobile unit, where it is automatically held until the user presses a SEND function key. When this key is pressed, the mobile unit initiates the call attempt by sending a digital message, which includes the called telephone number, to the Mobile Telephone Switching Office. A telephone set with preorigination dialing must incorporate three functions normally performed at the switching office: (*i*) storing the dialed telephone number, (*ii*) clearing both prior numbers and dialing errors from the storage register, and (*iii*) forwarding the contents of the storage register to the network to initiate a call.

Human factors studies were conducted to develop calling procedures that are easy to learn and remember, that minimize the chance of making a serious error (e.g., losing a call), and that require only one-hand operation.

5.1 Storing dialed numbers

The studies show that users do not need a "dial tone" or other start-to-dial signal from the mobile unit. Indeed, it is better to permit drivers to initiate dialing at a convenient opportunity and pause after every one or two digits to review the driving environment. Therefore, the

* Acoustic sound pressure level measured in decibels relative to 0.00002 Pascal with A frequency weighting.

mobile unit should always be ready to accept numbers as they are dialed and enter them in its storage register. In addition, the user should receive a tone feedback signal from a loudspeaker in the control unit each time a dial button is pressed.

5.2 Clearing prior numbers

The studies indicate the user should not be required to clear the storage register of the last number called before dialing the next telephone number. Instead, the mobile unit should automatically clear the register when the first digit of the new number is dialed. However, if the user does not dial a new number, then the last number called should remain in the storage register. This permits placing calls to this last number as many times as desired merely by depressing the SEND key. In addition, the mobile unit should automatically clear the register when the first digit is dialed following (*i*) the initiation of a call to allow the user to enter a telephone number while conversing, and (*ii*) a time interval of two minutes or more after the previous digit was dialed to prevent the user from inadvertently entering two telephone numbers in the register. A power-off condition should also clear the storage register.

It was found unnecessary to incorporate a separate CLEAR function key, such as those found on pocket calculators, for clearing the register after a dialing error. It is simpler to combine this function with the call termination function in one END function key. Thus, a user would depress the END key to correct a dialing error, and then redial the number properly.

5.3 Initiating calls

In the AMPS system, the mobile unit stores the number dialed by the user; it does not interpret the digits in order to detect errors, determine when dialing has been completed, or perform other call processing functions. The end-of-dialing function has been delegated to the user, while error detection and other call processing functions continue to be performed at the switching office.

The human factors studies show that the user should perform the end-of-dialing function and thereby initiate a call attempt only by pressing the SEND key on the control unit. This procedure prevents the occurrence of unintended call attempts from users who instinctively reach for the handset before dialing. Removing the handset from its cradle should not initiate a call. After experience with the mobile telephone unit, users will learn that they need not pick up the handset until after dialing and pressing the SEND key. However, the mobile unit will operate properly even if users first pick up the handset, dial, and then press the SEND key.

5.4 Answering and terminating calls

Calls are answered by removing the handset from its cradle; they are terminated by returning the handset to the cradle. Calls are also terminated by pressing the END key, which saves returning the handset to its cradle before placing a new call.

5.5 Status indicators

In land-line telephone service, the alerting signal is generated in the telephone set while the other call status signals (e.g., busy, reorder, intercept, and recorded announcements) are returned to the user from the telephone network. In the AMPS system, the reorder, intercept, and alerting call status signals must be generated within the mobile unit in response to commands from the Mobile Telephone Switching Office. The reorder signal sounds whenever a call attempt fails because of system conditions (e.g., all trunks busy); an intercept signal sounds in response to a user error.

The control unit has three visual status indicators to guide the user. These have been named IN USE, NO SERVICE, and ROAM. The IN USE indicator lights whenever a call is originated or answered, and goes off when the call is terminated. If the mobile unit is outside the radio coverage area of an AMPS system, then the NO SERVICE indicator informs the user. The ROAM indicator lights when the mobile unit roams into the service area of an AMPS system other than the one in which the subscriber is registered.

VI. SERVICE TEST CONTROL UNIT

The control unit for the AMPS service test is less than one-half the size of the control unit that the Bell System currently supplies its mobile telephone customers. The handset is placed on the side of the unit and behind the dial, and the base of the unit is shortened to the minimum length required to cradle the handset effectively (see Fig. 1).

This design includes a pushbutton dial having the same button size, spacing, and configuration found on telephone sets equipped for *TOUCH-TONE* calling. The handset, which is similar to the Western Electric K-type, is held recessed in its cradle by a hidden spring-retention latch. While the user can easily remove and replace the handset with a slight upward pressure against the spring, this same spring effectively restrains the handset against the longitudinal and lateral forces encountered in a moving automobile.

A loudspeaker built into the side of the unit supplies the reorder, intercept, and alerting call status signals, and allows the user to monitor call progress before picking up the handset. There are user-adjustable volume controls for the alerting signal and for both the speaker and handset received-audio signals.

Fig. 1—Control unit to be used in the service test.

6.1 Control layout

The controls and indicators are located on the unit's front surface, facing the driver. The two function keys (SEND and END) and the three mobile unit status indicators (IN USE, NO SERVICE, and ROAM) are grouped directly below the dial and above a "light island." The light island projects above the control surface and floods the controls with low-level illumination for night operation. The volume controls, a lock switch, and a telephone number card are located below the light island.

Recessed light-emitting diodes were chosen for the mobile unit status indicators; green for IN USE and yellow for both NO SERVICE and ROAM. Red is not specified because of its use as a hazard warning in the automobile.

6.2 Convenience features

In addition to the basic controls and indicators needed to place and receive calls, the control unit includes three convenience features. First, a pull-up card in a slot at the top of the unit serves as a minidirectory of frequently called numbers. Brief operating or calling instructions can also be listed as a reminder to the user. Second, placing the vehicle's ignition switch in either the "on" or "accessory" position automatically turns on the mobile unit and readies it for use. Turning the ignition switch off turns the mobile unit off, thereby preventing discharge of the car's battery. Third, a lock switch and associated visual indicator allow the user to deactivate and lock the mobile unit when leaving the car to prevent unauthorized use of the mobile telephone. The user unlocks the unit by dialing a 3-digit code preselected at the time the mobile unit is installed.

VII. ACKNOWLEDGMENTS

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REFERENCES

1. D. L. Huff, "AMPS: The Development System," B.S.T.J., this issue, pp. 249–269.
2. R. E. Fisher, "AMPS: A Subscriber Set for the Equipment Test," B.S.T.J., this issue, pp. 123–143.
3. "Preliminary Recommended Environmental Practices for Electronic Equipment Design," Environmental Standards and Test Methods Subcommittee of the Electronic Systems Committee, Society of Automotive Engineers, October, 1974.