THE BELL SYSTEM TECHNICAL JOURNAL

DEVOTED TO THE SCIENTIFIC AND ENGINEERING
ASPECTS OF ELECTRICAL COMMUNICATION

Volume 58 | January 1979 | Number 1

Advanced Mobile Phone Service: Introduction, Background, and Objectives

By W. R. YOUNG

(Manuscript received June 6, 1978)

This paper introduces a series of papers that describe in detail the Bell System's Advanced Mobile Phone Service (AMPS). It presents a brief history of mobile radio, highlighting the important events and legal decisions that preceded development of the AMPS system. The cellular system concept that has been embodied in AMPS makes large-scale mobile-radio service affordable to a sizable segment of the public. This concept calls for dividing transmission areas into "cells" to handle radio traffic, and, as traffic grows, subdividing those cells into smaller segments without increasing radio spectrum. This paper outlines AMPS objectives and sets the stage for more detailed articles on its evolution, its design and testing, and maintenance considerations.

I. INTRODUCTION

The potential for communicating with nonfixed points over the horizon without the use of wires was soon recognized following the invention of radio in the late 1800s and its development in the early 1900s. The first major use of this potential was to vessels at sea as an aid to navigation and safety. Since those early days, the use of mobile radio (as it is now called) has spread dramatically. Today it is used to communicate not only with ships at sea but with land vehicles, aircraft, and even with people using portable equipment.

The expanding need and concomitant growth have led to the development of the newest mobile system for common-carrier offering to the public, the Advanced Mobile Phone Service (AMPS),* the subject

* Known during developmental stages as High-Capacity Mobile Telecommunications System (HCMTS).

of this special issue of *The Bell System Technical Journal.* This system, in its mature configuration, will handle large quantities of mobile telephone traffic. High capacity will be achieved by dividing desired service areas into many small cells of radio coverage and, most important, by operating with the same radio spectrum utilized many times over within the service area.

This paper surveys the background and history of mobile radio, including governmental regulatory events, the development of systems used up to the present, and the emergence of new concepts and technology. The overview of AMPS introduces readers to the makeup, service objectives, and features of the new system.

II. BACKGROUND AND HISTORY

2.1 Early systems

In 1921 the Detroit police department made the earliest significant use of mobile radio in a vehicle.[1] That system operated at a frequency close to 2 MHz. The utility of this idea was so obvious that the channels in this low-frequency band were soon crowded.

New frequencies between 30 and 40 MHz were made available about 1940. A natural outgrowth of that development was the use of frequency modulation to improve reception in the presence of fading of the signal, electrical noise, and static. Opening the band encouraged a substantial buildup of police systems that started in the early 1940s and continues today.

Shortly thereafter, other users found a need for this form of communication. Private individuals, companies, and other public agencies purchased and operated their own mobile units and land (base) equipment. Over the years, the Federal Communications Commission (FCC) made available some 40 MHz of spectrum in bits and pieces between 30 and 500 MHz for various recognized and special uses. Today, approximately eight million licensed units enjoy this type of private service.* These systems are not generally connected directly to the telephone network.

In addition, the FCC has currently licensed over eight million citizens band radio units which are permitted to operate on 40 channels. An equal number of unlicensed units is also estimated to be operating on these channels. These figures graphically show that a great number of people want to communicate while on the move.

* In the early days, Bell System companies engineered, furnished, and maintained systems for private entities and public agencies such as police departments. This service was eliminated as a result of the 1956 consent decree: Final Judgment of January 24, 1956, in U.S.A. vs Western Electric et al.

2.2 Public correspondence systems

Immediately after World War II, the Bell System embarked on a program of supplying "public correspondence systems." The term means systems provided by a common carrier to permit communication among a variety of users that achieves large-scale economies by combining miscellaneous kinds of traffic into larger, more efficiently handled amounts. The FCC's official classification of this service is "Domestic Public Land Mobile Radio Service" (DPLMRS). (See Table I for a chronology of events in mobile radio history.)

The first of these public correspondence systems was inaugurated in 1946 to serve the city of St. Louis[2] with three channels near 150 MHz. The FCC had originally allocated six channels spaced 60 kHz apart, but the equipment was not sophisticated enough to prevent interference from adjacent channels being used in the same area. The St. Louis system was called an "urban" system.

In 1947, a "highway" system using frequencies in the 35- to 44-MHz band began operations along the highway between New York and Boston. These latter frequencies were thought to carry greater distances and, therefore, to be more useful in covering stretches of highway. However, these frequencies proved troublesome because of the skip-distance propagation phenomenon that carried unwanted conversations across the country. Today, the use of the 35- to 44-MHz band is declining.

Table I—History of mobile telecommunications related to common-carrier services

FCC Dockets		Service Offerings
	1946	First Bell System mobile service (150 MHz)
No. 8658, Bell System proposal for 40-MHz-bandwidth system	1947	Highway mobile service (35 MHz)
No. 8976, UHF TV, more detailed Bell System proposal for 40-MHz bandwidth system	1949	
	1956	First manual 450-MHz service
No. 11997, Bell System proposal for 75-MHz system at 800 MHz	1958	
	1964	First automatic 150-MHz service — MJ
	1969	First automatic 450-MHz service — MK
No. 18262, Allocation to common carriers		
— 75 MHz, tentative	1970	
— 40 MHz, firm	1974	
Open to "any" common carrier	1975	
Illinois Bell request for developmental authorization	1975	
Developmental authorization granted	1977	
	1978	AMPS Developmental System trial (850 MHz)

Both the urban and highway systems employed push-to-talk operation (somewhat unfamiliar to the ordinary telephone user) and were severely limited in the number of channels available. Nevertheless, more systems of both types were installed for cities and highways around the country. In many cases, the demand for service was such that the available channels could serve only a fraction of the demand for traffic and prospective customers had to be put on backlog lists.

Around 1955, the number of channels available at 150 MHz was expanded from 6 to 11 by the creation of new channels between old ones (i.e., channel spacing of 30 kHz). The year 1956 saw the addition of 12 channels near 450 MHz and the installation of the first system in this frequency range. All systems operated in the "manual" mode, with each call to or from a mobile unit handled by a special mobile operator. Mobile service still operates on a manual basis in some areas today.

In 1964, a new system, called the MJ, was developed and installed to improve efficiency, to reduce costs, and to achieve trunking advantage in cities having multiple channels. This system operated at 150 MHz, furnished automatic channel selection for each call, eliminated the need for push-to-talk, and allowed customers to do their own dialing. Most systems installed since 1964 are automatic, and many of the predecessor manual systems have been replaced.

In 1969 the automatic capability was extended to the 450-MHz channels with a system called the MK. The MJ and the MK were parts of the Improved Mobile Telephone System (IMTS),[3] the current standard for mobile service. In some respects, especially in convenience of dialing, the service given to IMTS customers is commensurate with that obtained with land-line telephones.

Present-day mobile telephone service requires a single land transmitter station positioned at a high elevation so that received signal levels at mobile units are substantially above the ambient noise throughout most of the desired coverage area. For each channel, the output power of the land transmitter is typically 200 or 250 watts, and transmitting antenna gain is sometimes used to raise the effective radiated power to 500 watts. Such a system ensures coverage as far as 20 or 25 miles from the transmitter site. Although the signal level on a channel may be poor beyond 25 miles, it is still high enough to interfere significantly with other mobile communications on the same frequency within 60 to 100 miles of the land transmitter. Consequently, two land transmitters spaced more closely than this should not use the same mobile telephone channel frequency. If land transmitters on the same frequency are farther apart, each can serve mobile units within about 20 miles with only minor interference, because any mobile unit is much closer to the land transmitter serving it than to any interfering transmitter.

From its inception to the present, mobile service has remained a scarce luxury. Each month, mobile telephone customers typically pay 10 to 20 times as much for mobile service as for residential telephone service. Despite the cost, many telephone companies can cite long lists of "held orders"—unfilled requests for service—from people who want to become mobile subscribers. Market studies[4-7] have repeatedly uncovered a sizable demand at lower prices.

But even if the cost of mobile service could be reduced substantially, the primary factor that has hampered the spread of mobile service thus far has been the unavailability of spectrum. No new customers could be accommodated in many areas because only a few dozen channels are available for present-day service, and even these are fractured into several frequency bands and partitioned among different classes of service carriers.

Since 1949, common-carrier entities known as "Radio Common Carriers" (RCC), companies not providing public landline telephone service, have been given separate channels to furnish the same kind of mobile services as the wire-line common carriers (the Bell System and other telephone companies). With about the same number of channels available, they serve roughly the same number of customers. Table II shows the number of channels available for each type of carrier and the number of two-way mobile units served by each for the most recent year for which figures are available.

Compare the number (approximately 143,000) of RCC and wire-line common-carrier customers with the estimated 16 million or more private units not served by common carriers: the ratio is about 1:110.* There are many, both inside and outside the Bell System, who believe that this ratio reflects the number of available channels allocated to the different uses rather than the inherent demand for such services. The FCC has taken this into account in its most recent grant of 40 MHz of spectrum for use by common carriers.

2.3 Regulatory history

Since 1946, Bell System planners have been looking forward to the large-scale system they believed necessary to satisfy customer demands. Proposals for such a system were made from time to time, as described below. These generally were associated with FCC Dockets, as noted in the left-hand column of Table I.

In 1947, in connection with FCC Docket 8658, the Bell System asked for 12 more channels to use immediately in the same manner as the 6 already granted for urban service. Also requested was sufficient bandwidth for some 150 two-way channels from which large blocks of

* This is much smaller than the ratio of frequencies allocated (1:16) but is entirely consistent with the fact that the amount of traffic per mobile is much lower and channel loading is much higher in the private systems.

Table II—Channel allocations, number of mobile units, and number of systems

	Wireline Common Carriers			Radio Common Carriers	Total
	Bell	Independent	Total		
Number of two-way channels	23	23	23*	21†	54
MHz allocated	1.38	1.38	1.38	1.12	2.5
Number of mobile units (December 1977)	44,500	18,200	62,700	80,000‡	143,000 (approx.)
Number of systems (December 1977)	635	716	1,351	1,375	2,726

* Excludes 10 channels in the 35- to 40-MHz "highway" band, which are of limited and declining utility.

† Excludes the newest shared-with-TV channels in the 470- to 500-MHz band, since there has not been time for significant usage to build up.

‡ Projected forward from 1976 and earlier data.

channels could be assembled to achieve spectrum efficiency and capacity advantages. The planned 100-kHz spacing plus suitable guard bands (between mobile and land transmitters and between mobile and other services in adjacent bands) added up to approximately 40 MHz.

In 1949, a Bell System proposal representing a more mature plan for a broadband system was described in connection with FCC Docket 8976. This docket considered the disposition of UHF TV (470 to 890 MHz). The FCC decided at that time against providing a broadband mobile allocation in this band.

In 1958, the Bell System again made a broadband proposal, this time for a 75-MHz bandwidth (new estimated required spectrum) located at 800 MHz. This proposal was submitted as a response to an inquiry made by the FCC in its Docket 11997.

After considering the above proposal and the general pressure for more radio communications, in 1968 the FCC started Docket 18262, specifically addressed to the question of alleviating the large backlog of requests for frequencies for mobile use. Deliberating on requests for common-carrier service and for private-type service led the FCC to tentatively decide in 1970 to allocate 75 MHz for wire-line common-carrier use and 40 MHz to supplement private services. It proposed to do this by eliminating channels 70 through 83 in UHF TV and by using certain other pieces of spectrum from 806 to 947 MHz (a total of 115 MHz). The FCC invited industry to respond in 18 months with proposals for achieving communication objectives and demonstrating feasibility. In December 1971, the Bell System responded with a technical report which asserted feasibility by showing in considerable detail how a system might be composed.[8]

In 1974, the FCC made a firm allocation, different from the above: 40 MHz for wire-line common-carrier use and 30 MHz to supplement private services. The remainder of the 115 MHz was to be reserved pending further demonstrations of need. In doing this, the FCC strongly urged all suppliers to design their systems for greatest utility and spectrum efficiency.

Early in 1975, the FCC made some modifications in its 1974 decisions. One was to open the 40-MHz allocation for common-carrier service to "any qualified common carrier" rather than limit it to the wire-line carriers. In July 1975, the Illinois Bell Telephone Company filed a request to the FCC for authorization to install and test a developmental system in Chicago. This was granted in March 1977.

2.4 Emergence of key concepts

From our discussion thus far, it is obvious that the high-capacity system has been the result of planning and key concepts that have been emerging over a long period of time. Perhaps the first concept to be appreciated as necessary to an efficient, large-capacity operation was trunking, so much so that it was part of the proposal to the FCC in 1947. Trunking, as used here, is the ability to combine several channels into a single group so that a mobile can be connected to any unused channel in the group for either an incoming or outgoing call. This arrangement reduces blocking probability and greatly increases traffic-carrying efficiency relative to the situation in which a mobile unit can utilize only one fixed channel.*

One problem that bothered early planners was how to achieve full trunking advantage without requiring each mobile unit to be able to tune to every one of the channels in use for this service throughout the country. In those days, each new operating frequency required two quartz crystals and a position on the channel selector switch. The solution came when it became technologically feasible to construct a low-cost frequency synthesizer that could be set on any of a large number of frequencies but required only a small number of quartz crystals. While the basic idea is quite old, the circuit was made practical and economical only in the early 1970s. It is now taken for granted in ongoing planning.

The *cellular* concept and the realization that small cells with spectrum re-use could increase traffic capacity substantially seem to have materialized from nowhere, although both were verbalized in 1947 by D. H. Ring of Bell Laboratories in unpublished work. According to the

---

* The IMTS systems employ trunking to advantage, but the small number of channels in use in a given system (typically less than the 12 that could be assigned) limits trunking efficiency.

cellular concept, a desired service area is divided into regions called cells, each with its own land radio equipment for transmission to and from mobile units within the cell. It was further recognized that if the available channels were distributed among smaller cells the traffic capacity would be greater. Thus a system needing a relatively small capacity could use large cells, and, as necessary to achieve larger capacity, these cells could be divided into smaller ones. Each channel frequency can then be used for many independent conversations in many cells which are spaced far enough from each other to avoid undue interference.

From 1947 on, the teams planning the eventual system had faith that the means for administering and connecting to many small cells would evolve by the time they were needed. Those means did, in fact, become a reality with the advent of electronic switching technology.

Locating and *handoff* are concepts that come directly from the use of small cells. The act of transferring from one channel to another is called handoff. "Locating" is a process for determining whether it would be better from the point of view of signal quality and potential interference to transfer an active connection with a mobile unit to another land transmit/receive equipment, or perhaps to another land site.* The process entails sampling the signal from the mobile unit to determine if handoff from one voice channel to another is required. Since a mobile unit will sometimes move beyond the borders of one cell into another, it will be desirable to transfer the connection to an appropriate new cell.

The system, as presently planned, uses omnidirectional antennas when the cells are large. When smaller cells are created, directional antennas are used which divide each cell into three sectors, each served by an appropriate directional antenna at the cell site. This concept was introduced many years ago.† This advantageous arrangement reduces the amount of co-channel interference from surrounding cells and increases system capacity. It is covered further in Ref. 9.

The plan for increasing traffic capacity, as required, from a sparse system to a mature system in a given metropolitan service area, assumes the division of the large cells used at first into small cells as needed. The best method for achieving this is a growth plan developed in recent years (see Ref. 9).

III. OVERVIEW

This section gives an overview of the AMPS system, covering the objectives, the basic system, services and features, and additional problems and considerations.

---

* The prime purpose of this process is not to determine the geographic location of the mobile unit, although the geographical location is a statistical factor in performance.

† Described in Ref. 8.

3.1 Objectives

The major AMPS system objectives are discussed in the following paragraphs.

(*i*) *Large subscriber capacity:* The capability of serving a large amount of traffic to many thousands of mobile users within a local service area, such as a greater metropolitan area, within a fixed allocation of several hundred channels is essential to AMPS.

(*ii*) *Efficient use of spectrum:** The scarcity of radio spectrum as a public resource demands that it will be used responsibly. AMPS will use it efficiently, for unless this is achieved, AMPS would lack the ability to take care of the large anticipated traffic within the allotted band.

(*iii*) *Nationwide compatibility:* The FCC strongly urges nationwide compatibility. The objective means that mobile systems everywhere should provide the same basic service with the same standards of operation to be sure that a mobile station based in one place will achieve satisfactory service elsewhere.

(*iv*) *Widespread availability:* Studies of existing services show that it is important to many users to be able to roam far from their normal home system and still receive service. Neither this characteristic nor nationwide compatibility necessarily implies universal coverage. Wide-area coverage will be achieved gradually as metropolitan systems extend their coverage into surrounding suburbs, and finally along the principal road and rail routes between metropolitan centers.

(*v*) *Adaptability to traffic density:* Since the density will differ from one point in an area to another in a city and more remote points, and since all of this will change with time, an AMPS objective is to be adaptable to these variable needs.

(*vi*) *Service to vehicles and to portables:* While AMPS is conceived primarily for use with vehicles, an important objective is to make it compatible with portables (hand-carried). This should be possible with little or no compromise in the design of the land-based network.

(*vii*) *Regular telephone service and special services, including "dispatch":* In addition to regular telephone service, AMPS should provide specialized services, such as dispatch or fleet operation, and special features, such as abbreviated dialing.

(*viii*) *"Telephone" quality of service:* As for quality of service, the capability objective is essentially the same quality as ordinary

---

* A meaningful measure of spectrum efficiency is the number of simultaneous voice-communication paths that can be created per megahertz of spectrum and per square mile of area. This measure is useful where mobile terminals are statistically scattered throughout a service area.

nonradio telephone service. Since the types of impairments encountered are not always the same, it is sometimes difficult to ensure achieving identical quality. The goal is that the audio quality—faithful reproduction of voice and freedom from excessive noise and distortion—will not differ in overall effect as perceived by the user. It also means that service quality as measured by occasional blocking of the paths from customer to central office will not be noticeably greater than that encountered in the land network. This will be a very large improvement over current radio service, in which the pressure to accommodate many customers results in channel loading which frequently causes the probability of blocking to exceed 50 percent.

(*ix*) *Affordability:* A goal is to make the service affordable by a substantial portion of the public and of businesses. Cost economies due to large production runs will tend to make this possible.

3.2 Basic system

Figure 1 shows the basic structure of the system as presently planned. The service area to be covered is divided into an appropriate number of cells. Each cell site has radio equipment and associated controls that can effect the connection to any mobile unit located in the cell. The cell sites are interconnected to and controlled by a central Mobile Telecommunications Switching Office (MTSO). The MTSO is basically a telephone switching office with substantial capabilities for software control. It connects to the telephone network and also provides the means to perform maintenance and testing and to record call information for billing purposes.*

All of the above make up the land-based part of the AMPS system. The mobile units complete the system.

The frequency layout (channel assignments) plan, the plan of operation for the system, and the way objectives cited earlier will be achieved are described in Ref. 9.

3.3 Services and features

The basic service is a telephone in a vehicle and is analagous to the individual telephone in the nationwide telephone network.

Beyond this, the intention is to offer mobile users features ordinarily available to telephone users, with emphasis on those of particular value in the mobile environment. One feature not generally available

* In this overview, the MTSO is portrayed as a compact monolithic entity. In future practice, however, there may be multiple MTSOs, as required for achieving greatest economy and sufficient capacity.

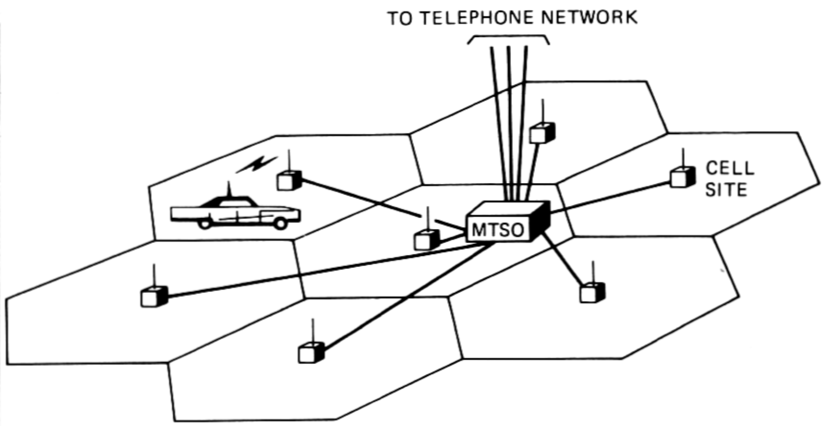

Fig. 1—The components and layout of the AMPS system.

in non-mobile phones, *pre-origination dialing*, will be included. This allows a customer to enter and store the called destination number before going off-hook. Then, when the user wishes to place the call, he begins the connection process by going off hook; the system uses this stored number to complete the connection. If the called line is busy or doesn't answer, the user may try again later without having to enter the same number again.

Eventually, the following vertical services, *Customer Calling Services,* furnished by ESS offices[10] may be made available for mobile users:

(*i*) "Three-Way Calling" permits a mobile user whose phone is already connected to another phone to originate a call to a third party, to switch back and forth between the connections, to bridge both connections as desired, or to connect the two other parties for continued conversation and then disconnect himself. With this feature, the mobile user can, for example, transfer a connection to another party.

(*ii*) "Call Waiting" furnishes a signal to alert the mobile user to an incoming call while a conversation is already in progress. By making use of the three-way calling feature, the customer will be able to transfer, accept the new call, and hold or terminate the former connection in progress.

(*iii*) "Speed Calling" permits a customer to originate a call to any of a few frequently called numbers by pushing one or two buttons. The connection is completed by the ESS in accordance with information stored there. This feature should be especially useful in a vehicle where a user cannot conveniently consult a directory or written notes. This feature will be implemented in the first working system.

In addition, it is expected that more features will be made available which can be implemented within the design of the mobile equipment. An example is "*Repertory Dialing,*" which is similar to "Speed Calling" except that the mobile equipment stores the numbers and completes the calls. This feature is more useful than speed calling for vehicles that roam from system to system and, therefore, need to carry their own repertory.

3.4 Additional considerations

Other plans for mobile communications include numbering and dialing, the provision for roaming from system to system, the provision of operator service, and tariffs and billing.

3.4.1 Numbering and dialing

Each mobile unit is assigned a 10-digit number (including area code). The mobile user will dial seven or ten digits with a 0 or 1 prefix, where applicable, as if calling from a fixed telephone. The adopted numbering plan places no requirements on the overall nationwide numbering plan; for example, no special office or area codes need be set aside to separate mobile traffic from other telephone traffic.

3.4.2 Roaming

A strong need for serving vehicles that roam has been identified. This capability is needed not just within a greater metropolitan service area, but to other service areas and along the highways between. The roaming capability will not be demonstrated in the Chicago trial,* but a method of operation for systems beyond the trial has been planned. Wherever there is a system to serve it, a mobile unit will be able to obtain completely automatic service.

However, a call from a land telephone to a mobile unit which has roamed to another metropolitan area presents additional problems. While it would be logically possible for the system to determine automatically where the mobile unit is, and to connect it to the land party, there are two reasons for not doing so. First, the land customer will expect only a local charge if the mobile unit's number is a local one, and the mobile customer may not wish to pay the toll difference. Second, the mobile user may not want to have his whereabouts divulged through this system, automatically, without his permission. To respect the customer's wishes in this regard, the system will complete the connection only if the extra charge is agreed to, and only where it is possible without unauthorized disclosure of the service area to which the mobile unit has roamed.

* Identified in Section 3.5.

3.4.3 Operator services

Standard operator services will be available to mobile users. No special operators or operator services (except possibly for handling the roaming situation) will be required for the AMPS system.

3.4.4 Tariffs and billing

The MTSO will record connect and disconnect times, location information, and call-destination information as required for billing. The recorded information will be tailored to the needs of tariff and charging algorithms, when these have been determined.

3.5 System tests and trial

Tests to provide information for system planning, establishing feasibility, and implementing of AMPS have been conducted relevant to different aspects of the AMPS system. Most of these were directed at learning about radio propagation, radio noise and interference, antenna characteristics and performance, etc.

Currently there are two major "tests" of the AMPS system: (1) The Cellular Test Bed (CTB) in Newark, N.J., and (2) the Developmental System in Chicago, Ill. Since these are described fully in Refs. 11 and 12, respectively, in this issue, the discussion here is kept brief. Suffice it to say that the former is a system laid out geographically to simulate a mature cellular system and permit measurements of coverage and interference in an actual urban layout. It does not simulate the whole service involving mobile customers, but is a "laboratory in the field." The Developmental System is an initial installation of a system implemented to serve mobile users, and will demonstrate the service itself as well as its implementation. But since the Developmental System employs relatively few large cells, it is not intended to demonstrate operation of a fully mature, small-cell layout. These two major endeavors complement each other and, taken together, provide a demonstration of all the major features of AMPS.

As explained later, the trial of the Developmental System has two phases. The first, which started in July 1978, is called an "Equipment Test," has about 100 mobile units, and is intended to "shake-down" the system and demonstrate that the system operates satisfactorily. The second phase, following the Equipment Test, is called a "Service Test," involving approximately 2100 users, and will demonstrate the service aspects of the system.

IV. SUMMARY

This first paper of the series has provided a general introduction to and overview of AMPS. The papers that follow describe more completely the cellular concept, control architecture, voice and data transmission aspects, the Cellular Test Bed, and the Developmental System. Other papers describe the Mobile Telecommunications Switching Office, the subscriber set used in the equipment-test phase of the developmental system operation, the mobile telephone control unit used in the service test, the hardware used at cell sites, and laboratory test systems that were devised to obtain operational data during system tests.

REFERENCES

1. W. C. Jakes, ed., *Microwave Mobile Communications,* New York: John Wiley, 1974.
2. "Telephone Service for St. Louis Vehicles," Bell Laboratories Record, *24,* No. 7 (July 1946), pp. 267–268.
3. H. W. Nylund and R. M. Swanson, "Improved Mobile Dial Telephone System," IEEE Trans. Veh. Commun., *1* 1963, pp. 32–36.
4. "Communications Tomorrow: Who? What? Which? Where? Why? and How Much?" Communications; Part I (October 1972), pp. 42–45; Part II (November 1972), pp. 20–23.
5. "World Mobile Telecommunications," Cambridge, Mass.: Arthur D. Little, 1974.
6. "A New Era in Mobile Communications," Raymond Kraus, Consulting Communications Engineers, Inc., 1976.
7. "The U.S. Mobile Equipment Market," Report No. 556, May 1978, Frost and Sullivan, Inc.
8. Bell Laboratories, "High-Capacity Mobile Telephone System—Technical Report," (December 1971), submitted to the FCC.
9. V. H. MacDonald, "AMPS: The Cellular Concept," B.S.T.J., this issue, pp. 15–41.
10. Bell Laboratories Record, *46,* No. 6 (June 1965), page 210.
11. G. C. DiPiazza, A. Plitkins, and G. I. Zysman, "AMPS: The Cellular Test Bed," B.S.T.J., this issue, pp. 215–248.
12. D. L. Huff, "AMPS: The Developmental System," B.S.T.J., this issue, pp. 249–269.