The first North American mobile telephone system

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ABSTRACT

The first general-availability mobile telephone system (in the sense of a system that extended the telephone network to mobile users) in North America was introduced by the Bell Telephone System in 1946. It was called the Mobile Telephone System (MTS) and had two "versions", one operating in the 30-50 MHz band and one in the 155 MHz band. There were a limited number of channels allocated, and even in a large city not all of them could be used, owing to the need to reserve some for nearby cities. There was no short-distance frequency reuse, such as we have today in the various cellular systems. As a result, in the typical large city, there could only be perhaps 12 mobile telephone calls in effect at any time. The system was wholly manual, the services of a special operator being required for both incoming and outgoing calls. This article describes the essential features of this system and its implementation. An appendix describes in detail the operation of the ingenious electromechanical selector used to recognize an incoming call for a mobile station.

1. INTRODUCTION

1.1 General

The first general availability mobile telephone system in North America was introduced by the Bell Telephone System in 1946, and was called the Mobile Telephone System (MTS).[1] It had two "versions" called the "highway" and "urban" mobile telephone systems. The highway system used duplex channels in the 30-50 MHz band (the "VHS-low" band), and the urban system used duplex channels in the 155 MHz band (the "VHS-high" band).[2]

The intended uses of the two branches are as their names suggest. The highway system was intended for, for example, long-haul

[1] I will for convenience here refer to the Bell Telephone System as the provider of this service. In fact, in cities where local telephone service was provided by a non-Bell company, that company would often offer the service. Although they would likley use equipment different from that used by a Bell company, the systems were wholly operationally compatible.

[2] The highway system overall was technically designated the "MB mobile telephone system", and the highway system the "MC mobile telephone system"

truckers, “traveling salesman”, and the like. The urban system was intended for use by customers primarily traveling within a metropolitan area. Both systems were also used to provide service to vessels operating on the Great Lakes and on various inland waterways.

The greater “reach” of the 30-50 MHz signals used in the highway system was of course consistent with its intended usage.

1.2 Channel allocation

The number of channels allocated (in the US, by the Federal Communications Commission, and by the comparable agency in Canada) varied over the life of the system. For our purposes, to allow grasp of the overall situation, we will think in terms of there being 10 channels available for the highway system and 11 channels for the urban system (13 in Canada).

1.3 Duplex channels

The channels were *duplex*, meaning that there were separate frequencies allocated for inbound and outbound transmission. The base station transmitted on the higher of the two frequencies. In the highway system (VHF-low band), the two frequencies were separated by 3.000 Mhz. In the urban system (VHF-high band), the two frequencies were separated by 5.260 MHz.

1.4 No privacy

I will note at this point that there was absolutely no privacy for users of this system. When a user was on a call using a certain channel, any other mobile station that operated solely on that channel, or could be switched to operate on that channel, could hear the conversation by merely taking to hand the station handset.

1.5 System architecture

For each system, there was a primary base station, typically located at the Bell Telephone operating company’s main building in the city. This installation comprised, for each channel, a transmitter-receiver pair and a *control terminal*, which administered the channel and provided the interface with the telephone network (through a special manual switchboard).

Secondary receiving stations were located at locations in the near suburbs (and for the highway system, perhaps in more distant locations), again typically at telephone company central office buildings. These were linked by telephone lines to the control terminals at the primary base station.

1.6 Channel deployment and utilization

In the various cellular telephone systems used today for mobile telephone service, a given channel frequency may be simultaneously used at several base stations in a given service area, separated by a modest distance. This is one key to the large traffic capacity of such systems.

But in MTS there was no such short-distance frequency reuse. A channel used at one city could typically only also be deployed perhaps 35 miles or more away, in order to prevent mutual interference.

If we consider the urban system at the time in the channel allocation evolution at which there were 11 channels available, in a fairly large city it might only be practical to deploy perhaps 7 of them, the remaining 4 needing to be reserved for deployment in other (smaller) cities perhaps 25-30 miles away.

Thus, in that hypothetical large city, there could only be, in the urban system, a maximum of 6 telephone calls active at any given time. There could be another perhaps 5 calls active in the highway system, for a total maximum of 11 calls in, perhaps, a metropolitan area of one million residents.

In the next section, we will learn of another matter that limited the overall traffic capacity of the system.

1.7 Channel assignment to mobile stations

Each mobile station was assigned a specific channel in the channel repertoire for the “system” (highway or urban) through which it was served. A mobile station could only ever receive calls over its assigned channel (and it had to use that channel for the duration of the call), and for a basic station, it could only originate calls over that channel as well. Thus, if the mobile station wanted to place a call, or if there was an incoming call for it, and that channel was busy on another call (with another station), the call could not be completed. This of course provided a limit on the efficiency of use of the small set of channels in operation in any city.

Later, mobile stations we made that allowed the user to choose one of two channels (even later, one of perhaps as many as six), but only in its system’s band, to place an outgoing call. This provided a modest improvement in the traffic capacity for mobile-initiated calls. However, calls to the station could still only be completed over its assigned channel, so this feature provided no increase in the traffic capacity for calls to mobile stations.

1.8 Channel use during a call

1.8.1 *Channel busy determination*

When a mobile user wanted to place a call, he took up the handset and listened to see if the channel used by his station was busy on a call. (Yes, as noted earlier, there was absolutely no privacy on this system). If he heard a conversation (or the distinctive tone signaling sequence used to establish a call to a mobile station), he knew that the channel was busy, and he would have to wait until later to place the call.

If the station was equipped to operate on two, or even more, channels, the user could operate the channel switch to listen on the alternate channels, and if one was found to be idle, leave the station set to that channel and initiate the call. That channel would be used for the entire duration of the call.

When he replaced the handset, a buzzer sounded to remind him to return the channel selection switch to his "home" channel position so that his station could receive incoming calls, which always arrived over that channel.

1.8.2 *"Half-duplex" operation*

When a call was "up" on a channel, the transmitter for that channel (located at the "primary" base station) transmitted continuously. At the mobile stations, operation was "push to talk". When the user, on a call, wished to speak, he pushed a button in the handset. This turned on the mobile station transmitter, switched the antenna from the receiver to the transmitter, and muted the output of the receiver. (As there was no duplexer at the mobile station, it would not have been possible for the receiver and transmitter to actually operate simultaneously.) At the end of his "sound bite", he released the button, and the receiver was put back into effect.

This mode is sometimes spoken of as "half-duplex" operation, a term borrowed (not too carefully) from telegraph operation.

1.8.3 *Receiver voting*

Each time a mobile station began to transmit, each of the receivers (at the primary base station or at secondary receiver stations) that detected the signal on a "usable" basis would send a DC signal over the line joining them to the control terminal to so indicate. The onset of this signal was intentionally delayed by a small amount which depended on the measured signal strength, a shorter delay for a stronger signal.

At the control terminal, the receiver whose control signal arrived first (and which was therefore assumed to have the best radio reception from the mobile) had its output coupled into the telephone connection. This scheme is often described as "receiver voting". The process was done anew each time the mobile user pressed the push-to-talk switch.

2. STATION EQUIPMENT

2.1 Introduction

The original "classical" MTS station comprised the following:

- Western Electric 38- or 39-type transmitter (38-type for the highway system, 39-type for the urban system)
- Western Electric 38- or 39-type receiver (same distinction as above)
- Western Electric 41A control head
- Antenna to suit the frequency band.

2.2 Transmitter and receiver

In figure 1, we see a 38 type transmitter and its matching receiver in a typical installation, in the vehicle trunk.

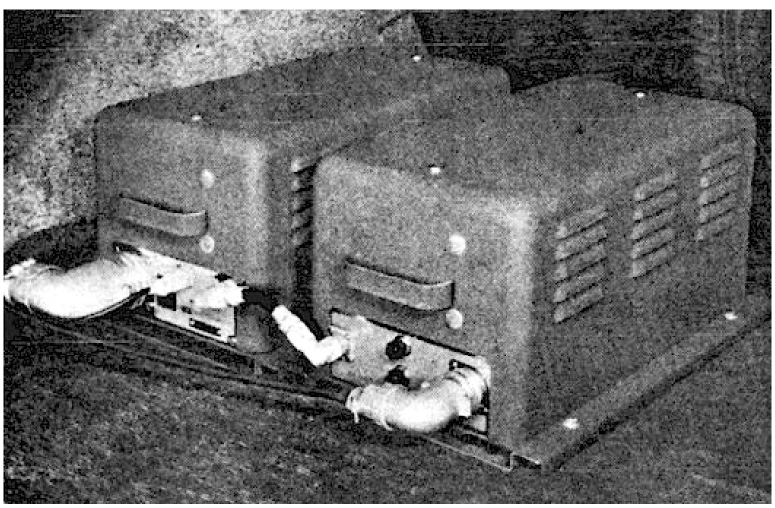

Figure 1. Western electric 38-type transmitter and receiver

Photo from Geoffrey C. Fors, WB6NVH; original source unknown.

The basic designs of the transmitter and receiver were essentially the same as for equipment used at the time for service in police, fire, and taxicab systems. In fact, the 38/39-type units were derived from Western Electric units already in use by Bell Telephone System "leased" systems for police, fire, and taxicab use.

But there was a major difference in the receiver. The 38/39 type receivers had the demodulating circuitry for the tone signaling system used to address a mobile station, the specialized electromechanical selector that recognized a mobile station's unique selection code, and various control relays used in that process.

The transmitter output, as I recall, was on the order of 35 watts.

The station was powered from the car's 6 VDC electrical system (later there were stations designed for cars with the newer 12 VDC systems). The receiver s powred by a vibrator power supply, much as was widely used in car broadcast radios. The transmitter was powered by a *dynamotor* (essentially a 6/12 VDC motor driving a perhaps 300 VDC generator, with a common field assembly and integrated rotor).

2.3 Control unit

The user's "telephone" was called a *control unit*. In figure 2 we see a 41A control unit, used in the earliest normal MTS station configuration.

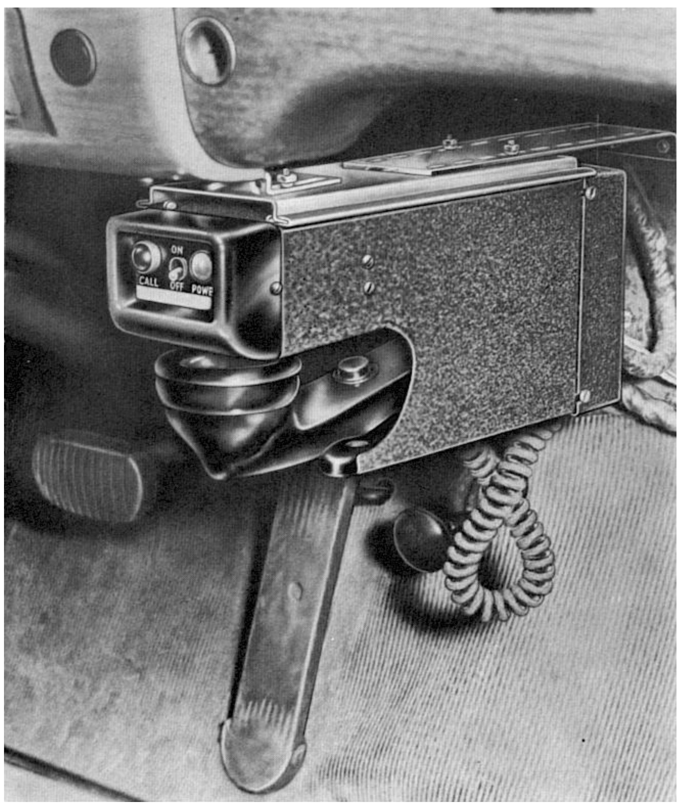

Figure 2. Western electric 41A control unit

Photo from Geoffrey C. Fors, WB6NVH; original source unknown.

This was usually mounted under the dashboard, as seen here. A special F-type handset (the same basic design used in the 302 series of telephone sets), with a push-to-talk button, was held in a pocket with a spring-loaded bottom plate which prevented the handset from slipping out or rattling about. (The pocket had a slot to allow the coiled handset cord to dangle freely.)

A small DC bell was contained in the housing. Under a removable rear cover was a terminal strip for connection of the multi-conductor cable running to the transmitter and receiver.

2.4 Other configurations

Other configurations were used over the years. In the early one shown in Figure 3, the transmitter and receiver were made by Motorola, custom-specified versions of their popular "two case" (colloquially, "turkey oven") style widely used for police, fire, and taxicab systems. On the right is a Western Electric 106A selector set. This had the tone signaling demodulation circuit, electromechanical selector, and associated control relays needed for handing calls to the mobile station.

Figure 3. MTS station with Motorola receiver and transmitter

Photo from Geoffrey C. Fors, WB6NVH; original source unknown.

Some other variations, some spawned by regulatory changes, will be discussed later.

In any case, two large cables had to be run to the car's trunk, a large-gauge single conductor cable to bring the 6/12 VDC power from the car's electrical system to the transmitter and receiver (the current drain while transmitting was substantial) and a multi-conductor cable running to the control head.

2.5 A newer control unit

An important later improvement was the replacement of the 41A control unit with the 47A control unit. Figure 4 shows a later version, the 47E control unit, but the physical appearance is essentially identical. Among other things, this design allowed greater flexibility of physical mounting, especially as the space beneath the dashboard became more and more cluttered.

Figure 4. Western Electric 47E control unit

Photo by Geoffrey C. Fors, WB6NVH;

The 47A control unit used a special G-type handset (basically as used in the 500-type telephone set), again with a push to talk button (but here, it was a rectangular bar). A key operated power switch was built in[3] (a key-operated switch in an external box could be attached to a 41A control unit).

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[3] The locks in these switches were arranged for operation with a master key, presumably so a mobile unit could be activated for maintenance if the regular key was not available (perhaps the car had been brought to the maintenance shop by the chauffeur, and he had forgotten to ask Madame for the key). But curiously enough (perhaps the result of a decision at Bell System headquarters), master keys were not distributed to the field, and most maintenance shops had no idea there was such a thing. The result was that if a unit arrived for maintenance with no key, the control

The 47A had a short multiconductor "pigtail" cable, which was connected to the cable running to the transmitter and receiver at a small junction box, mounted under the dashboard (often on the firewall). The little DC bell was no longer in the control head proper but was also in that junction box.

Later versions of the 47-type control head offered various design improvements. The latest, the 47E (actually shown in figure 4), has a small piezoelectric buzzer in it, taking the place of the little bell in the junction box for alerting the user to an incoming call.

2.6 Antennas

Many types of antenna were used in MTS station configurations. With regard to the urban system (VHS-high band), my favorite was the Western Electric KS-15510 List 1 antenna, seen in figure 5.

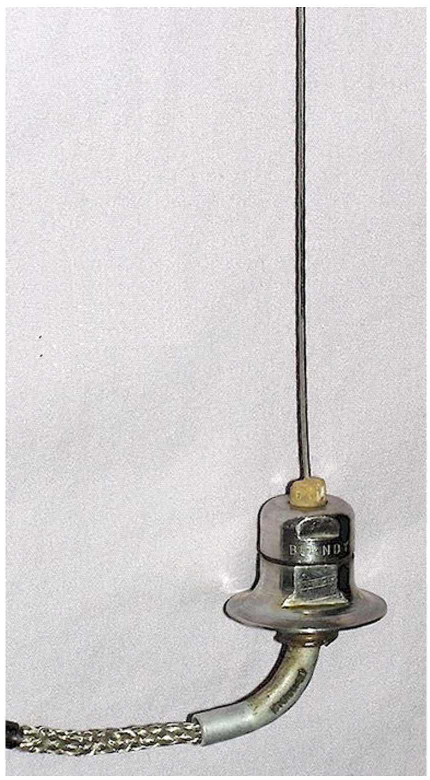

Figure 5. Western Electric KS-15510 List 1 antenna (element not completely shown)

Photo by Geoffrey C. Fors, WB6NVH;

It was originally made for Western Electric by H. H. Buggie & Company of Toledo, Ohio. Manufacture was later taken over by Burndy Corporation (the unit shown in figure 5 is a Burndy unit).

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unit was removed and junked and a new one (shipped with its key, of course) installed. The chauffeur was given the new key to give to Madame.

This was a basic 1/4-wave monopole, which depended on being mounted on a metal surface (typically the car roof, or in some cases the trunk lid) for its ground plane. The element was approximately 19" long.

The mounting arrangement was simple but effective. Under the "base" of the antenna was a short, fat male thread essentially like that of a sheet metal screw. A hole (27/64" diameter) was drilled in the sheet metal of the mounting surface, and the antenna base was just screwed into it, making primitive "threads" in the sheet metal as it went (the base had flats so an open-end wrench could be used). There was a rubber gasket under the base to seal the resulting arrangement against any water leak.

Of course when the antenna was mounted in the car roof (the preferred situation), often the cloth headliner had to be temporarily removed so that the antenna cable could be routed to the rear window pillar, through which it made its way to the trunk, where the radio equipment was mounted.

3. CALL HANDLING

3.1 General

The MTS system was "fully manual". All calls to and from MTS stations were handled by special operators, for most of the life of the system working at special dedicated switchboard positions.

3.2 Numbering plan

Each MTS station had a telephone number of this form: YJ5-4284. This was seemingly consistent with the "2-5" (or "2L-5D") numbering scheme that would come into use for all telephone stations beginning in about 1950. But the significance of the number's components was quite different from regular telephone numbers.

The two letters gave the station's assigned channel. The channels for the highway system all started with the letter "Z" [4], while those for the urban system started with the letters "J" or "Y".

The five digits were the "selection code" for the station, used to "address" it in the case of an incoming call. As we will see later, for a call to the station, a sequence of those five digits was sent over the

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[4] Initially, two of the original five channels in the Urban system had identifiers beginning with "W", but those channels were discontinued when 8 additional channels were allocated (10 in Canada).

channel assigned to the station (with a special tone signaling system, to be described later), was recognized by a selector in the station, and caused the telephone to "ring" (and an indicator lamp to light), indicating an incoming call. (With an optional feature, the user could turn on a switch that arranged for the horn to blow upon receipt of the signal for an incoming call, in case the user was out of the car at the time.)

3.3 Outgoing call operation

To place a call, the user took the handset out of the control head, which activated the receiver (we will assume that the user does not have a multi-channel system, and thus the receiver was tuned to the station's assigned channel). The user listened to see if the channel was already in use. (As you can now see, there was absolutely no privacy in this system). If not, the user briefly pressed the push-to-talk button in the handset handle, which turned on the mobile station transmitter for that brief time.

The detection of the radio signal carrier by one of the receivers on that channel, conveyed by a DC signal to the control terminal, brought up a lamp associated with a jack for that channel at each position of the mobile telephone switchboard. An available operator would plug the back cord of a cord circuit into that jack and operate the talk key for that cord circuit (connecting the operator's headset to the cord circuit). Plugging in the cord caused the control terminal to turn on the transmitter for that channel, and both the transmitter and the chosen receiver were now in communication with the operator's headset.

The operator would say (for example), "Cleveland mobile operator". The mobile user would hear that, would press and hold the push-to talk-button, and would say (for example): "This is YJ5-4284. Please give me BOulevard 5569[5] (that is, 26-5569)."

The operator would plug the front cord of the cord circuit into a "tandem jack" and dial (or keypulse) 26 5569, which would extend the call through the local telephone network to the local station whose number was BOulevard 5569.[6]

[5] I illustrate here operation with 7-digit local telephone numbers, as would have been the case for most large and medium size cities at the time MTS was introduced.

[6] The details of that aspect of call handling might differ from that described as a consequence of different arrangements of the local switching system, but this description should serve to illustrate the overall scenario.

The operator, using essentially the same procedure as would have been used for a toll (long distance) call, wrote the calling number (YJ5-4284) and the called number (BO-5569) on a "call ticket", and stamped the current time on the ticket with a special time stamp, called a Calculagraph. (MTS calls were charged by the minute.) When the call was answered (as the operator could see from the "front cord supervisory lamp" on the cord circuit going dark), she had the Calculagraph stamp the time of answer.

When the "land" party hung up, the front cord supervisory lamp lit again. The operator had the Calculagraph, in effect, stamp the ending time on the ticket (this was done in such a way that later the elapsed time of the call could be later read from the ticket by a billing clerk with no need for any arithmetic), and pulled both cords of the cord circuit out of their jacks. The pulling out of the front cord caused the telephone switching system to take down the "land-side" connection. The pulling out of the back cord (from the channel jack) caused the control terminal to turn off the transmitter.

3.4 Incoming call operation

Imagine that the local user at BOulevard 5569 wanted to call the mobile station whose number was YJ5-4285. The caller would dial "0" to reach the *dial service assistant* (the formal name for what was colloquially called "the operator"). The caller would ask for the "mobile operator". The dial service assistant would extend the call to the mobile telephone switchboard (that happened in one of several ways, depending on local arrangements, but the differences are of no concern to us here).

The mobile operator would plug the front cord of a cord circuit into the incoming trunk jack and answer "mobile service operator" or such. The user would ask for "YJ5-4284". The mobile operator would look at the jack for channel "YJ" and observe a busy lamp which would be lit if the channel was busy. If so, she would advise the caller that the mobile station could not be reached just now. If not, she would plug the back cord of the cord circuit into that jack. This would cause the control terminal for channel "YJ" to turn on the transmitter for that channel.

The mobile operator would then dial "54284" on her position dial. This caused the YJ control terminal to send out the digit train "54284" in a two-tone signaling system we will describe shortly.

At each mobile station (in range of the base transmitter) operating on channel YJ, this digit sequence was received, and was observed by an electromechanical selector. At each station that selector had been "programmed" for the selection code (five digits of the telephone number) for that station.

At station "YJ5-4284" (only), that selector would respond to the transmitted selection code. A relay was operated that caused the bell in the control unit to ring and lit the incoming call lamp.

If the user was there and wanted to take the call, he pulled out the handset and pressed the push-to-talk button, turning on his transmitter. The receiver receiving the best signal (under the "receiver voting system") was connected into the connection by the control terminal, and the mobile operator's back cord supervisor lamp went dark, indicating that the call had been completed. The user said "hello" or whatever was his practice, released the push-to-talk button, and the call was underway.

The mobile operator recorded the call on a ticket, using the Calculagraph to capture the times, in essentially the same way as before.

As before, it was when the land party hung up that the mobile operator knew to disconnect the connection.

4. THE SIGNALING SYSTEM

A unique tone signaling system was used to alert the called mobile.

The system was essentially a "frequency-shift telegraph system". The two frequencies were 600 Hz and 1500 Hz. During the transmission of the station's "selection code", each transition from one of those frequencies to the other (either way) constituted a pulse. As with dial pulse signaling, a digit was sent as the corresponding number of "pulses" (frequency alternations, in this case); the digit "zero" was represented by ten pulses. The digits were separated by periods of no alternations.

At each station the selector (traditionally, a Western Electric 66A selector) had programmed into it the sequence of five digits that made up the selection code for the station. Because of the way these selectors worked, there was not the ability to assign just any five-digit number. Rather, the sum of the five digits in any valid number (again with zero counting as ten) was always 23, and the digit "1" was never included.

The excruciating details of operation of the 66A selector are given in Appendix A.

When a call was being placed over a certain channel to a certain station, shortly after the base transmitter was activated a 600 Hz tone was applied on the outbound side of the channel. After a short period, the tone transitioned to 1500 Hz. This constituted one pulse. There were never any digits “1” in a number, and it turns out that if a single pulse is received, the selector mechanism is reset to its starting condition (in case it was not already resting there, which could be the case for various reasons).

Then, the pulses of the first digit of the selection code were sent, each pulse via a reversal of the tone frequency. Just as in dial pulsing, the end of the digit was marked by a period of no pulses (reversals). Then the next digit was sent, and so forth, until all five digits had been sent.

At the station whose selector had been programmed to recognize that station’s selection code, the selector closed a contact, operating a relay that caused the little bell to ring and the “call” lamp to light.

A few seconds after the last digit was sent, there was a final reversal of the tone frequency, and then the tone transmission ended. This final reversal, again constituting a single “pulse”, reset the selector and ended the ringing of the bell. But a locking relay kept the “call” lamp lit until the user answered the call by pressing the push-to-talk button on the handset.

5. SYSTEM EVOLUTION

5.1 UHF channels for MTS

Eventually, a third form of MTS was introduced to provide further capacity in urban areas. This utilized channels in the 460 MHz band, and was known (from the designation of that band) as the “UHF system”. There were 13 channels allocated for this system. The duplex separation was 5.00 MHz (again, the land station transmitting on the higher frequency).

Operation was essentially as described above for the highway and urban versions of the MTS.

No Western Electric mobile station equipment packages were made for the UHF MTS. Integrated station sets (transmitter, receiver, and a selector, sometimes solid-state) were made by various mobile radio manufacturers to Bell Telephone System specifications. I will not discuss these station sets further in this article.

5.2 IMTS

The fully manual operation of the Mobile Telephone System was out of keeping with the overall mechanization of the telephone network (among other things, system operation was very labor-intensive). Further, the fact that calls could (for most stations) only be placed over one predetermined channel, and in any case calls to a station could only be completed over one predetermined channel, meant that the call handling capacity of the system was substantially less then the theoretical potential of the already-limited repertoire of channels.

To mitigate these limitations, an advanced form of the Mobile Telephone System, known as the Improved Mobile Telephone Service (IMTS) was introduced by the Bell Telephone System in 1964. It initially operated only in the “urban” (VHF-high) band, but later a version of the system operating in the UHF band was introduced.[7]

IMTS provided for fully automatic operation. Land callers (in the service area of the mobile station) could just dial the number of the wanted mobile, and mobile users could originate calls using a dial on the new type of control unit. Figure 6 shows one standard type of IMTS control unit.

Figure 6. Bell Telephone System IMTS control unit

Photo from Geoffrey C. Fors, WB6NVH; original source unknown.

A scheme of channel administration that today would be called “trunking” essentially allowed any idle channel in operation in an area

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[7] The VHF-high band version of the system, overall, was technically designated the “MJ mobile telephone system”; the UHF band version was the “MK mobile telephone system”. MK-system stations could not operate in the manual (“MTS” mode) with UHF-band MTS systems.

(in the frequency band the station was equipped for) to be used for a call from or to the station. This substantially increased the traffic capacity of the system for any number of deployed channels.

There were provisions for the gradual conversion of users from MTS to IMTS. For one thing, any "IMTS" station could be made to operate in the "MTS" mode when in an area that did not yet have an "IMTS" system. The "M" key seen on figure 6 put the station in that mode. The keys marked with the designations of the "urban" channels were used when operating in that mode to select the channel over which a call would be placed. As with a traditional multi-channel MTS station, when placing a call the user listened on the various channels until he found one that was "quiet" and thus idle and available for the call.

MTS stations could get service in an IMTS system. It would recognize their nature from the way in which they originated a call (just "keying their transmitter"), not following the IMTS signaling protocol.[8]

The actual replacement of MTS service with IMTS service did not occur in some areas for a number of years.

I will not describe this system further in this article.

5.3 Dial outgoing operation before IMTS

Prior to the emergence of IMTS, systems were implemented by some of the Bell Telephone System operating companies that allowed an MTS user to place a call without the intervention of the mobile operator. A dial on a special control unit was used for this purpose.

I will not describe these systems further in this article.

6. Regulatory changes

6.1 Leased private radio systems

As I glancingly mentioned earlier, at one time the Bell Telephone System operating companies offered, under lease, complete mobile radio systems for police, fire, taxicab, trucking and other applications. In the 1950s and 1960, these generally used the same kind of equipment (mobile units, base stations, dispatch consoles, etc.) as systems purchased or leased from equipment manufacturers or distributors. (In an earlier era, the mobile units in such systems might even have used Western Electric transmitters and receivers.)

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[8] In general, there were no longer the special MTS switchboard positions for manual mobile service, but provisions had earlier been made to handle manual mobile calls through the "cordless" operator positions then used for other operator traffic.

There were those who believed that this aspect of the Bell Telephone Company's business was unfair to competitive suppliers. Essentially, at that time, the local Bell companies had a monopoly on telephone service (in the cities in which they operated) and "the telephone companies" had a monopoly on long-distance service. It was argued that the economy of scale afforded by the Bell Telephone System's operations gave them an unfair economic advantage over other competitors in the leasing of "private" mobile radio systems.

This was one of several prongs of a large federal antitrust suit filed against the Bell Telephone System in 1949.

The suit was settled by a "consent decree" issued in 1956. One of its provisions was that the Bell Telephone System would no longer be permitted to provide mobile radio systems other than those that were clearly extensions of the telephone network and its service (like MTS).

In some of the existing installations, the customer was given the option to buy the system at a price established by some formula, but often that was not, for any of several reasons, attractive to the customer. Thus the Bell operating companies found themselves in possession of a large inventory of traditional mobile radio equipment.

One way to take advantage of this was to retrofit the stations as MTS stations. One thing this required was to equip the station with the tone demodulation and selector functions needed for handling MTS calls to the stations. In fact, several manufacturers developed just such retrofit "selector" packages.

I will not further discuss the general ramifications of this situation in this article.

6.2 Customer-provided MTS stations

Just as with "landline" telephone service, for many years the policy of the Bell Telephone System was that an MTS customer would subscribe to a complete service, and the Bell System operating company would provide (and install, and maintain) the station equipment.

There were a small number of customers who somehow had access to an operational MTS station and wanted to "bring their own station", presumably being able to pay a smaller monthly fee for the service under that premise.

The Bell System staunchly resisted such a notion, citing the fact that station equipment they had not given birth to, and did not have the opportunity to hover over, might not work properly, or even worse, might harm the network.

But a complaint against this policy was another prong of the 1949 antitrust suit, and one provision of the 1956 consent decree was that the Bell Telephone Companies must allow a customer to provide his own MTS station, although subject to careful vetting to make sure that it was compatible with the MTS system and would not cause the dreaded “harm” to the network.

Of course, in general, this didn’t happen very often. One could not go to the local electronics house and buy an MTS station package. One could easily get transmitter-receiver packages that would be perfectly suitable, but the selector system was another matter altogether, as was the matter of the control unit.

It was more common for IMTS customers to own their own stations.

6.3 Competitive systems

At the outset of MTS, the Federal Communications Commission in the US, and its counterpart in Canada, only established one set of frequency allocations (in each of two bands) for mobile telephone service, that of course being for MTS as operated by the Bell Telephone System (or non-Bell local telephone operating companies).

But there was a camp that felt this was unfair, and so (in one of the earliest moves in the direction of competitive common carrier commentation services), some time in the early 1960s the FCC established a second set of channels for mobile telephone services to be operated by licensed entities that were not a local telephone company, called “radio common carriers” (RCCs).

Thus in many areas there was available a competitive mobile telephone service.

There were different system operation and signaling protocols established for use in these services by various equipment manufacturers. Unlike MTS, there were not continent-wide standards for any of those matters, and thus subscribers to such services could not always take advantage of the system of that type when traveling. Many said that was unfair to the competitive aspect of mobile telephone service. But to cure that would have required the establishment of a complete structure of standard protocols, and the industry was not motivated to take that on.

But this two-competitor doctrine set the stage for the “licensing” structure of the cellular telephone system, to come before long.

7. Decline

The introduction of the cellular mobile telephone system in 1983[9] promised to quickly obsolete the MTS/IMTS systems[10], but full deployment of the new system across the country did not complete until about the early 1990s. In any case, many subscribers to the older system were fiercely loyal to it, and vehemently resisted its decommissioning. It had special staying power in various rural areas, especially in Canada.

Some MTS/IMTS systems remained in operation until the mid-1990s.

8. Acknowledgements

Thanks to Geoffrey C. Fors, WB6NVH, for his wonderful series of Web pages on the MTS and IMTS systems. They can be found here:

http://www.wb6nvh.com/Carphone.htm

Many of the photos in this article have been “lifted” from those pages.

Thanks to Sam Hallas, a retired telecommunication engineer of the railway persuasion, for the nice discussion of the STC equivalent of the Western Electric 60A selector (from which the 66A selector was derived) on his Web site discussing a multistation railway telephone line system, and for the nice photo used as the basis of figure 8 (in Appendix A).

These photos are used here without benefit of any explicit permission from the above sources, under the doctrine of fair use. But thanks so much, guys.

Thanks to Carla C. Kerr for her careful and insightful copy editing of this difficult manuscript.

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[9] It was introduced by the Bell Telephone System, where it was formally designated the Advanced Mobile Phone system, or AMPS.

[10] I say “MTS/IMTS” because some subscribers still had MTS stations and utilized the IMTS system in its MTS mode.

Appendix A

Operation of the Western Electric 66A selector

The "traditional" Bell Telephone System MTS station included a Western Electric 66A selector, a clever electromechanical device whose purpose was to consider any pulse sequence received, by tone signaling, over the station's channel to see if it matched the assigned selection code for the station (which was the numerical part of the station's mobile telephone number). Its overall function was described in the body of the article, but here we will look into the details.

Figure 7 shows a 66A selector.

Figure 7. Western Electric 66A selector

Photo by "oldradiosnstuff" (e-bay seller)

The 66A selector was essentially identical to the earlier 60-type selector, which had been used for many years for station addressing purposes on multi-station telephone lines used in railway operation.[11] The main physical difference was that the connections were made to the 60-type selector on a number of screw terminals (4, 5, or 6, depending on the specific selector model), and it was held down with four screws, whereas the 66A selector had a 14-pin connector on its bottom, and was held down by four captive quarter-turn fasteners,

[11] The earliest official document I have describing the 60-type selector (or equivalent) is dated 1925, but I have seen it said that it goes back to 1916 or so. So it is not surprising that the 66A selector seems rather "old timey".

both of these features allowing it to be more quickly replaced when needed.

Like the 60-type selector, it is enclosed in a glass housing, rather a tradition in railway signaling and communication apparatus.

In figure 8 we see a closeup of the parts of the selector we will be discussing.

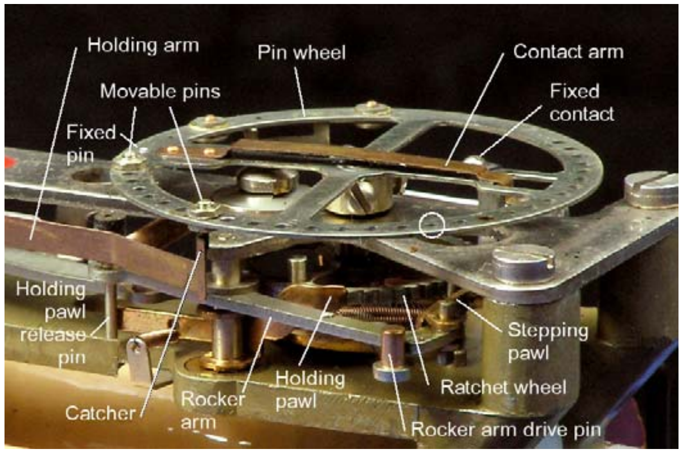

Figure 8. STC 4301 selector details (similar to Western Electric 60A and 66A)

Adapted from a photo by Sam Hallas
Hitchin, Herts, UK

This is actually what is almost identical to a Western Electric 60A selector, but made under license by STC, a European company with a historical connection to Western Electric, the only picture I had available. The parts shown are basically identical to those of the 66A selector for our purposes. But some details of the unit portrayed will not match the details of my story. I'll deal with that as I go.[12]

The heart of the selector is a rather large wheel (labeled "pin wheel"), provided with a hairspring that urges it toward its "zero" position. A spring contact on the tip of a spring arm on the wheel ("contact arm") makes contact with a fixed contact when the wheel reaches its "destination" position.

The selector has a large polar-neutral electromagnet (we see one of its two large coils in figure 7). The armature of such an electromagnet is moved in one direction or the other from its center position by current in the windings, the direction depending on the direction of the

[12] Most notably, the selector operation I will describe is for a five-digit code (54284) in a system with a pulse total of 23. The unit shown in the figure is set up for a three-digit code (872) in a railway telephone system with a pulse total of 17.

current. With no current, the armature stays decisively in its center position (the "neutral" part of its description).

In the mobile receiver or selector set, a polarized relay moves to one position or another depending on whether the tone being received is 600 Hz or 1500 Hz. If there is no tone, the relay remains in its last position (always one position of the other, never in the "center").

The contact of the polar relay applies voltage of one polarity or the other to the windings of the electromagnet in the selector, causing its armature to move to one side or the other. But the voltage is applied through a capacitor.

Thus, if the polar relay remains in one position or the other for a period of time (as it will when there is no alternation between the two tones, as when between digits of the signaling sequence), the current through the selector electromagnet winding decays, and the armature goes to the center position. We will shortly see the significance of this.

Imagine first that we are in a digit, when the tone frequencies are alternating, and so is the polarity of the voltage applied to the selector electromagnet. The electromagnet thus stays in one side position for a short while (one pulse period), then travels very quickly to the other side position, and so forth.

As the armature goes to **either** "side" position, a *rocker arm* carrying a *stepping pawl* advances (there is sort of a mechanical "full-wave rectifier" involved; the *rocker arm drive pin* seen in the figure is half of this). The pawl, when advanced, pushes on a *ratchet wheel* on the shaft carrying the *pin wheel*, advancing the wheel assembly by one "step".

At the next reversal, the armature begins to travel to the other "side", which initially results in the stepping pawl being withdrawn from the ratchet wheel. But a conventional *retaining pawl* prevents the ratchet wheel from falling back.

As the armature reaches nearly the center position (but still on its way to the other side), the retaining pawl is withdrawn (and remember the stepping pawl has earlier been withdrawn). But as the armature moves quickly through its center position, the retaining pawl is soon allowed to drop back into place, and as the armature continues its travel to the "other side" the stepping pawl is again driven into the ratchet wheel, "catching" the ratchet wheel and then advancing it one more step.

Now, it might seem that, during the time the armature is near the center position, with both the stepping and holding pawls disengaged, the wheel assembly would drop back. But this situation persists for only a **very** short time (the armature is moving rapidly), and the inertia of the wheel assembly prevents it from quickly beginning to fall back. Before it has fallen back a significant amount, the stepping pawl again plunges into the ratchet wheel (as described above), catching the ratchet wheel and then advancing it one more step.

Next assume that the current digit is complete, and thus the reversal of the tones halts. The voltage applied to the selector electromagnet stays at the current polarity (which could be either way). Because that voltage is applied through a capacitor, the current through the electromagnet winding decays toward zero, and shortly the electromagnet armature falls to its center position. In this state, the stepping pawl and holding pawls are both withdrawn, freeing the wheel assembly to fall back to “zero” under the influence of the hairspring.

Unless one of the pins comes into play.

There is a pin in the wheel at each spot to which the wheel would have advanced, cumulatively, after each digit of the station’s specific selection code. Thus, for the code 54284, there would be movable pins placed in positions 5, 9, 11, and 19, and a permanent pin in position 23.[13] If the wheel reaches 23, a contact is closed, which operates a relay that rings the bell and so forth to announce the receipt of a call.

There is a *holding arm,* actually a flat spring. It has at its end a little “catcher”. The spring force of the arm makes it want to move so that its catcher end is slightly **inside** the circle of the pins. When the electromagnet is in its center (deenergized) position, the catcher end of the arm is held **outside** the pin circle. When the electromagnet is in either “side” position (energized with one polarity or the other), the arm is free to move under its own spring force so that its end would go inside the pin circle.

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[13] The specimen illustrated is set for the three-digit code 872, having a pulse total of 17. Thus there are movable pins at positions 8 and 15 (the circled pin position is position “0”) and the fixed pin at position 17. The holes “at and below zero” would never be used in this setup, but would be needed for use of this selector in an application with codes having a greater pulse total, in which case the pinwheel would be set differently on its shaft. The two rivets seen in positions beyond the “fixed” pin hold a special plate that is engaged by the holding arm in a special mode used in railway telephone line operations, allowing a time signal to be received on the station’s alerting bell. The 66A selector has no such special plate. Rather, in that region are three additional ”fixed” pins, the purpose of which will be explained later.

That is, unless there is at the time a pin at the place where the catcher travels inward. In that case, the catcher engages the pin.

Now back to operation. Imagine that the first digit of the transmitted selection code is “5”, and that the first digit of the selection code for this station is not “5”. The five reversals of the armature position for this digit cause the pawl to advance by 5 steps from “zero”. At the end of the digit, the electromagnet armature goes back to the center. The pawls are withdrawn, and so perhaps the wheel will be free to be pulled back to “zero” by the hairspring.

Ah, but what about the holding arm? It is free to move its catcher from outside the pin circle to inside the pin circle, unless there is a pin at the current position, in which case the catcher engages it.

But in this example there is no pin at this position, so the catcher arm does not engage a pin, but rather completes its motion to the inside of the pin circle. Thus the wheel is in fact free to fall back to “zero” under the influence of the hairspring, and it does so. The wheel’s journey to position 23 is doomed (for this outing).

Now suppose that we are at a station for which the first digit of its selection code **is** “5”. The scenario for the first digit is as described above. Here, however, after the first digit, when the pawls are withdrawn for long enough that the wheel could fall back, there **is** a pin at this position of the wheel.[14] As the catcher arm moves inward, it catches the pin (as seen in the illustration), and the wheel does not fall back. It has safely completed the first leg of its journey to position 23.

This story continues for each digit. If at the end of a digit, there is no pin at that wheel position, the wheel falls back, and its journey is doomed. But if each time at the end of a digit there is a pin for the catcher to grab, the wheel’s journey continues, ultimately resulting in the wheel reaching position 23, where the contact arm contacts the fixed contact, which operates the relay that rings the little bell and so forth.

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[14] Recall that, as mentioned earlier, the selector illustrated is actually set for a three-digit code, with a pulse total of 17, the code for this one being 8-7-2. So we actually see the holding arm catcher on the first pin, at position 8.

Now suppose that we are receiving a series of reversals, and the wheel is advanced by one step for each one, but there is a pin at an intermediate position which the wheel is "stepped past".[15]

As the electromagnet armature makes its transition from one side position to the other, the pawl is briefly withdrawn, and the holding arm is briefly free to move inward. In this case, its catcher encounters a pin. But as the armature continues its motion to its new side, the holding arm is again forced outward, coming clear of the pin. Its brief engagement with a pin has no effect.

MTS station selectors came from the factory with the pins placed to program them for code "44546", which is never assigned as a mobile station selection code (the numerical part of its mobile telephone number).

I did not yet mention here the single transition of tone frequency that occurs before the sending of the five digits commences.

For various reasons, before the beginning of the code sequence, the selector wheel might have been inadvertently advanced (by one of various events) from "zero" to a spot where the catcher arm has caught a pin to hold the wheel assembly there. The initial tone reversal is essentially a digit value of "1" (which never occurs in an actual selection code[16]). Thus there would be no pin at the **next** position for the catcher to catch and the wheel falls back to zero, rendering the selector ready to begin properly contemplating the actual digit train.

I also did not yet mention here the final reversal of tone frequency that occurs a few seconds **after** the sending of the last digit. If we consider a station that had received its own selection code, and the wheel was thus at position 23, closing the contact that caused the bell to ring, this reversal (again like a digit "1") would cause the holding arm to be pulled outward, freeing the wheel, which would be stepped to position 24), where there would be no pin, and the wheel would then go back to the zero position.

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[15] This would of course only be so at a station whose selection code was not the one being sent, but we must consider it. Perhaps 54284 is being sent, and we consider a station whose code is 25493. Its selector has a pin at position 2, and when the first 5 is sent, the wheel steps past that pin position.

[16] If the digit "1" appeared in a selection code, there would need to be two movable pins placed in adjacent positions in the wheel, and considering their physical deign, that would not be possible.

This of course breaks the "position 23" contact, which causes the ringing of the bell to cease. However, a locking relay keeps the "call" lamp lit on the control unit until the user answers the call by pressing the push-to-talk button on the handset.

As was mentioned earlier in a footnote, there are actually four fixed pins on the 66A selector pin wheel, at positions 23 (already explained), 25, 27, and 29.[17] And there are actually four fixed contacts, which would be contacted by the contact arm in those four positions.

It is of course the first such contact, at position 23, that is normally used to alert the station to an incoming call. However, in special situations, a station may be arranged to have two, three, or even four numbers, for example 54284, 54286, 54288, and 54280. Each of those numbers will be recognized by the selector at that station but with a separate contact being closed.

These separate contacts would activate different call alerting signals, perhaps with different kinds of bells and/or different indicating lamps. Thus, calls could perhaps be directed to several different people who might be in the vehicle (imagine a mobile geological laboratory, for example).

The astute reader may notice (for example in figure 7) that the holding arm looks to be mounted insulated from the frame and has an electrical lead connected to it. This can be used to detect if in fact the holding arm catcher is on a pin (the wheel is grounded). But, to my knowledge, that capability is not used in the operation of the selector in a normal MTS station.[18]

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[17] This can be seen in figure 7 if you look carefully at the upper right portion.

[18] In the case of the 60-type selector from which the 66A selector is descended, that connection was used for some special purpose in the operation of multistation railway telephone lines. In one case, it was part of the circuit that sent back over the telephone line a "tone", generated by a contact on the bell as it vibrated, that confirmed to the caller that the called station was in fact being "rung".