The step-by-step telephone switching system: handling of toll calls

Douglas A. Kerr

Issue 1
April 6, 2020

ABSTRACT AND INTRODUCTION

In the 1920s and 1930s, the US had a well-developed, and very complex, system for handling long distance ("toll") telephone calls, much of it operated by The Bell Telephone System.

Step by step (SXS) switching equipment played two major roles in that scheme. Even during the era in which connections through the "interior" of the toll network were set up with manual cord switchboards, the completion of a toll connection to a subscriber served by an SXS system was done with a special part of that system, using special versions of the SXS switches.

Then as the system evolved, special types of SXS switching equipment were used in the interior of the toll network, allowing the toll operator who initially handled the call to, by dialing, set up the entire toll connection all the way to the called station.

These SXS switching arrangements use control and signaling arrangements quite different from those of the SXS equipment used for local calls. These in part arose to support special modes of call handling traditionally used in the long distance service.

In this article we get an insight into how these SXS switching arrangements worked. It begins with extensive background on the surrounding context. The basic overall architecture of a toll call, as of the period of interest, is shown. Then the two switch trains involved are described in detail from a functional viewpoint. Next the signaling and control protocols are described. Finally, the features supporting several specialized requirements are described.

1 GENERAL

1.1 Caveat

This entire area is extremely complicated, and comprehensive, authentic documentation is hard to come by. The author has relied on a wealth of information, including patents from the era of interest, but not every explanation "reaches from cover to cover". Accordingly, in my detailed descriptions there will be some loose ends.

1.2 Reader background

It is assumed that the reader is generally familiar with the operation of the SXS (SXS) telephone switching system. If more information is needed, I commend the reader to the lead article of this series, "The step-by-step telephone switching system–Overview".

1.3 The hardware

The SXS switches described in this article use basically the same mechanisms, and operate in generally the same ways, as the switches used in "local" SXS switching systems, although there are some very significant operational differences, the most important of which will be described at length in this article.

1.4 The term "toll"

Long distance cases early became described as "toll" calls in recognition of the fact that they were normally charged for "by the each", the charge (a "toll") generally depending on the duration of the call and the distance between the two stations. This was as distinguished from local calls, which generally were either "free" (that is, an unlimited number were included in the monthly change for the service) or charged for as a small fixed amount after some "free" ration has been used).

Then, the modifier "toll" became used in the names of almost everything involved in long distance service (toll switchboards, toll operators, toll central offices, toll cables, toll switching machines, toll transmission plans etc.).

2 TECHNICAL BACKGROUND

2.1 The step by step local switching system

For reference and comparison, figure 1 shows in simplified block diagram form an **intraoffice** local connection between two telephone stations served by a step by step (SXS) switching system.

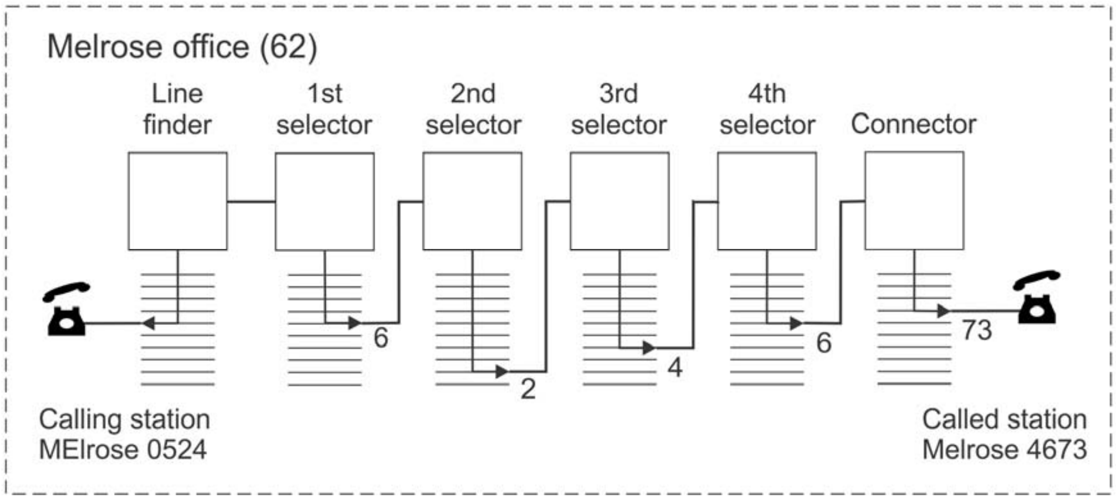

Figure 1. Local intraoffice step by step connection

The example presumes six-digit telephone numbers, with the first two digits indicating the serving central office (which in this example is the same central office that serves the calling station).

Then, to complete the picture, figure 2 shows in the same way an **interoffice** local connection between two telephone stations served by SXS switching systems in different central offices..

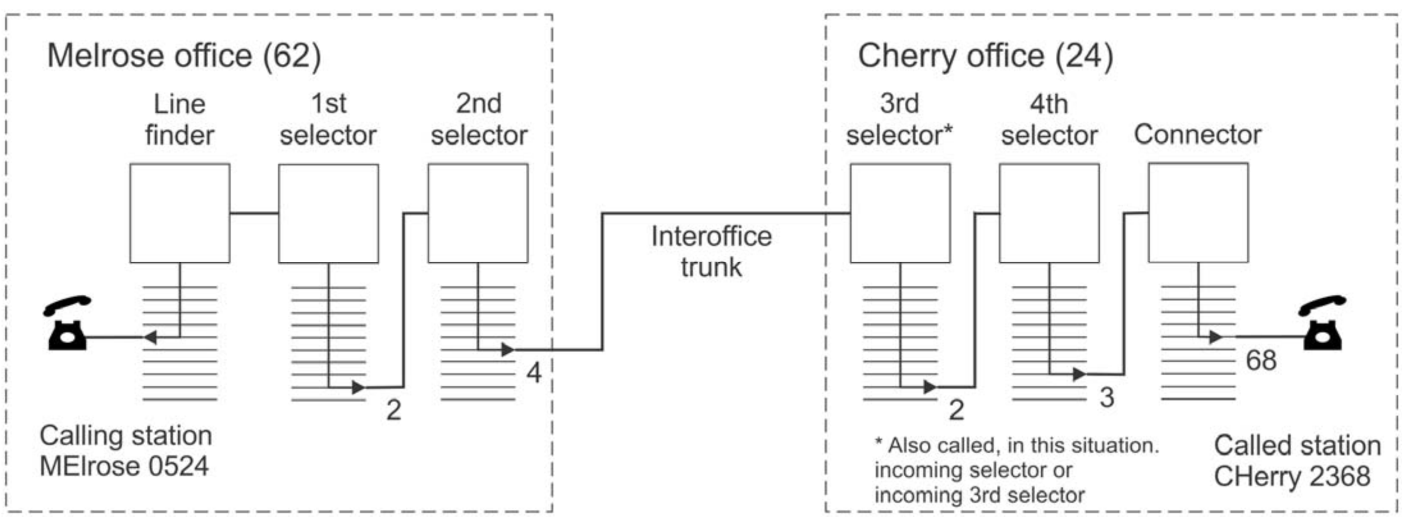

Figure 2. Local interoffice step by step connection

2.2 About "battery"

In the field of telephone systems, the DC voltage that is used for many purposes (energizing telephone lines, operating relays in switching equipment, etc.) is referred to as "battery". This flows naturally from the fact that traditionally that this voltage (typically nominally 24 V in manual switching systems, 48 V in "machine switching" systems) is provided by a storage battery "floated" across the output of a DC power supply.

2.3 Talking battery feed

2.3.1 *The carbon transmitter*

From the introduction of the *common battery* mode of operating telephone lines through perhaps the 1980s, almost all telephone sets used a transmitter (microphone) of the *variable-resistance carbon* type. Here, the diaphragm, responding to the acoustic speech wave, flexes a conductive wall of a small chamber filled with carbon granules. The opposite wall is also conductive. As the pressure through the mass or carbon granules changes, the resistance through the mass (between the two conductive walls) varies.

A nominally-constant DC current is passed through the transmitter. As its resistance changes so does the voltage across it, following the acoustic wave. The varying component of that voltage is an AC "audio"[1] signal reflecting the speech.

For a given acoustic input, the level of the electrical output signal varies significantly with the level of the DC current.

2.3.2 *Battery feed*

In all but some specialized cases, under the *common battery* principle, the DC current that energizes the transmitter the DC current that flows in the telephone line, supplied from the serving central office. Given its importance to the operation of the transmitter, it is often spoken of as *talking battery*.

In many cases, the circuit that feeds the DC current is closely integrated with the circuit that couples the speech signals between the two sides of the switch (or other circuit).

In figure 3, we see where the battery is applied in our example **intraoffice** local connection with SXS equipment once the connection is completed.

---

[1] But we never say "audio" in this context, Rather, such signals are called "speech" or "voice frequency" signals.

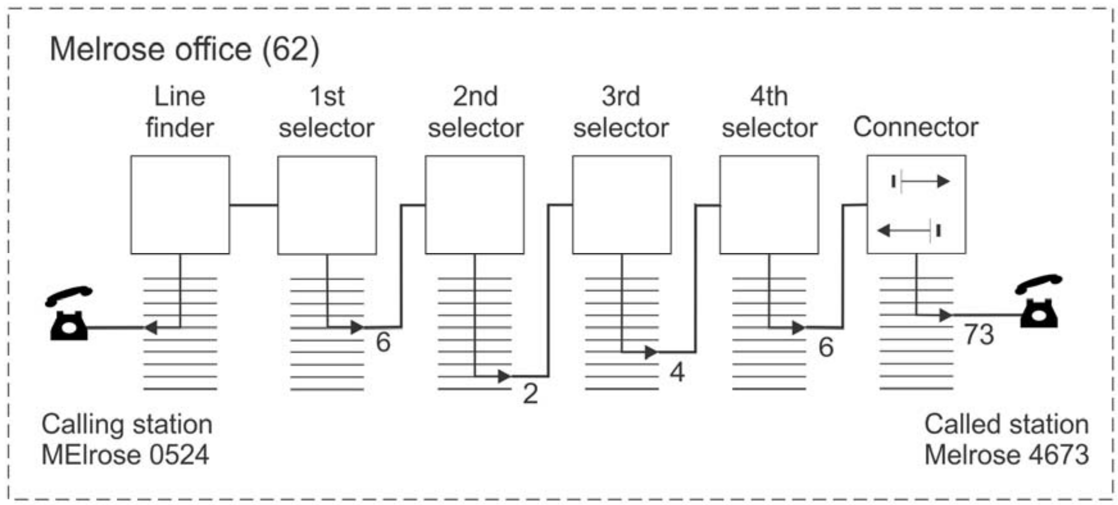

Figure 3. Local intraoffice step by step connection–battery feed

We see that the connector feeds the battery to both stations.

In figure 4, we see where the battery is applied in our example **interoffice** local connection with SXS equipment, again after the connection is completed.

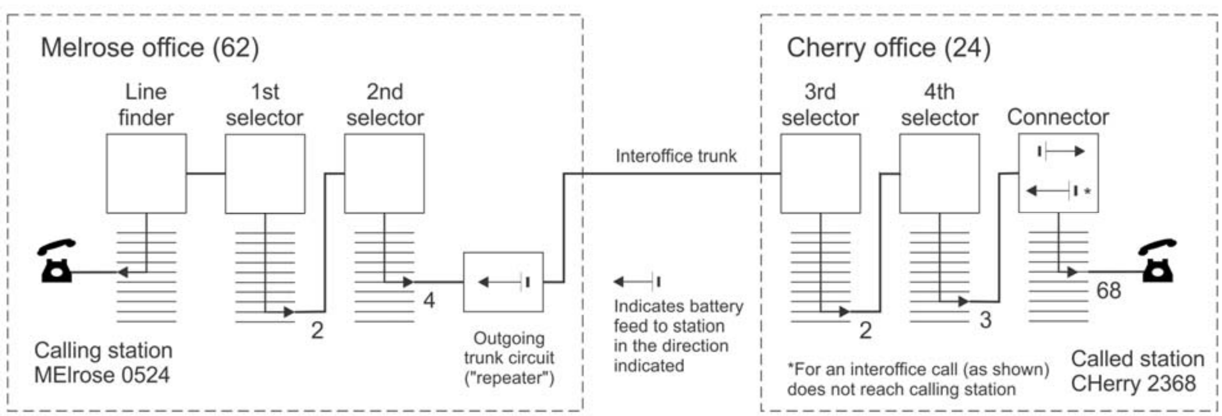

Figure 4. Local interoffice step by step connection–battery feed

We note that, as in the intraoffice case, the connector provides talking battery both "forward" (to the called station) and "backward", but here the latter does not reach the calling station. Rather, in this case, the talking battery is feed to the calling station from the trunk circuit[2] at the near end of the interoffice trunk.

---

[2] Actually called a "repeater", since one of its purposes is to repeat the dial pulses over the interoffice trunk.

The reason it is done this way is that the combined resistance of the interoffice trunk and the calling station line might reduce the current below a desirable level were it in fact provided from the connector.

Keep this structure in mind for later when I will discus departures from it in the operation of the toll network.

3 DELIVERY OF A TOLL CALL—THE TOLL TRAIN

3.1 General

If we consider, for example, the early 1930s, switching in the interior of the toll network was, with a very few exceptions, done on a totally manual basis, with special cord switchboards. Consider that context for now.

Suppose now that the called subscriber in a toll call is served by an SXS office. Then the call is "delivered" from the last manual toll switchboard in the interior of the connection to the called line by a special train of SXS switches. Although this train, the "toll train", directly parallels a corresponding part of the local switch train, there are many important differences in its operation (which is in fact one point of this article).

In figure 5 we see one example of a toll connection, manually switched in the toll network proper, delivered to a called station served by an SXS local office.

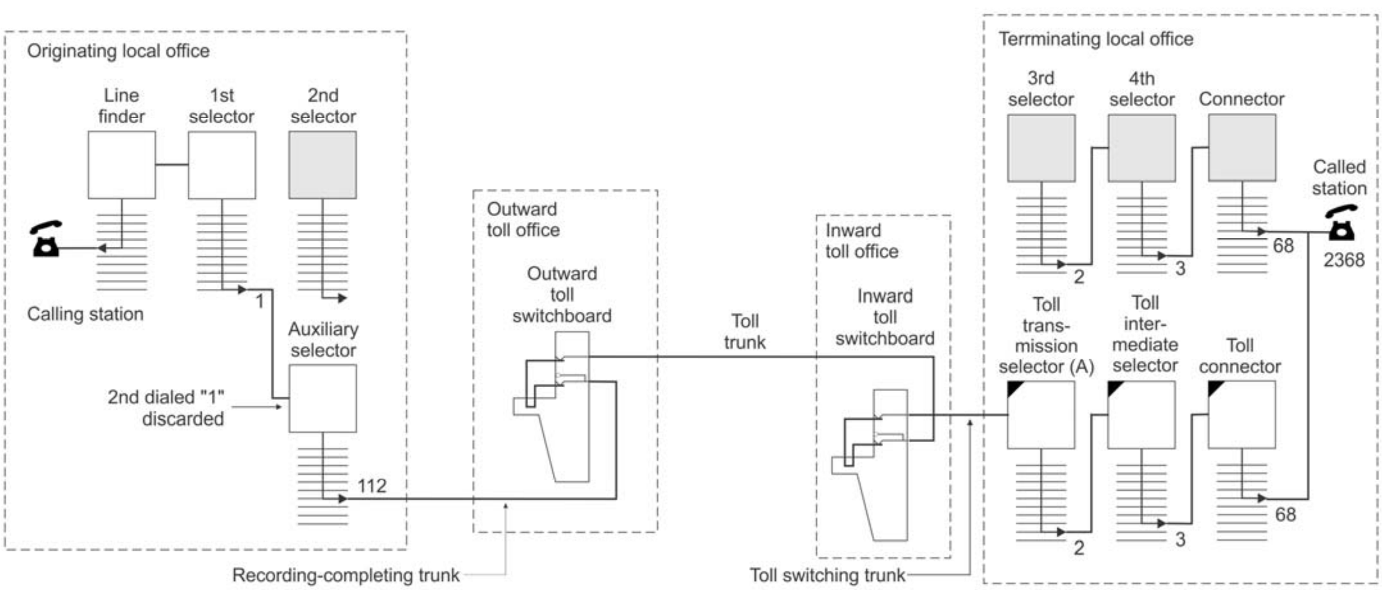

Figure 5. Completion of a manual toll call

In this example, the connection in the toll network proper is a simple one, involving only two manual toll switchboards, known as the *outward* and *inward* toll switchboards, with a *toll trunk* between them.

The operator at the outward switchboard is responsible for the call, and will administer it from beginning to end. The operator at the inward toll switchboard is responsible for extending the connection to the toll train at the destination office, but she then stands back until the call is finished and the outward toll operator releases the connection.

In the example, the calling station is also served by an SXS office. As was often the case in this situation, the caller dials 112 to reach the "long distance operator". The first dialed 1 takes the *1st selector* to level 1, where it reaches an *auxiliary selector*. Several other services reached by this selector also have three-digit codes beginning with "11" (*e.g.*, "information"[3], 113). The strategy for handling that scheme is that the auxiliary selector would "discard" a dialed (second) digit of "1".[4] Then, in this example, the third digit, "3", takes the auxiliary selector to level 3, where it accesses a trunk to an outward toll switchboard.[5]

The caller passes the wanted city and telephone number to the outward toll operator. From her "Rate and Route Guide", she finds what group of trunks she should use to extend the connection to that city. In this example, I assume that there are direct trunks to the destination city–that is, to the inward toll board there.[6]

The outward operator selects an idle trunk in that group and plugs into it with her "calling" (front) cord. Through signaling that is beyond the scope of this article, this alerts the operator at the destination inward toll switchboard.

The outward operator passes the called number to the distant inward operator. The inward operator plugs into a *toll switching trunk*[7] to the office (SXS in this example) serving that number. The inward operator dials (perhaps four digits) into the *toll train*[8] at that office. There, two

---

[3] Known in modern times as "directory assistance", to avoid any possibility that customers would think that they could call this number to ask about the population of Argentina.

[4] This was actually called "digit absorption".

[5] This is called a "recording-completing" trunk for historical reasons that are beyond the current scope of this article.

[6] That inward toll switchboard may in fact serve many cities in the same area. It will have "toll switching trunks" to each of them.

[7] The name refers to the fact that the trunk leads to a "switching system", which in this case implies *mechanized* (that is, not including a manual) switchboard).

[8] Often said to be the *toll switching train*.

selectors (of two different special types) and a connector (of a special type) establish a connection to the called line.

I have marked the switches of the toll train, which are quite different in the details of their operation from the corresponding switches in the local train, with a little black triangle in the upper left corner.

I will discuss those differences later.

Note that the trunk labeled "toll trunk" could be appropriately called an *intertoll trunk*, since it runs **between** toll offices. But that term did not prominently appear during the era of the architecture shown. Keep it in mind, though.

3.2 Intertoll dialing

Beginning in perhaps the mid 1930s, switching in the toll network proper began to be "mechanized". The type of switching equipment that could be most expediently adapted to this was SXS equipment.

Figure 6 shows the result of a connection made in this way, again for the simplest connection in the interior of the toll network.

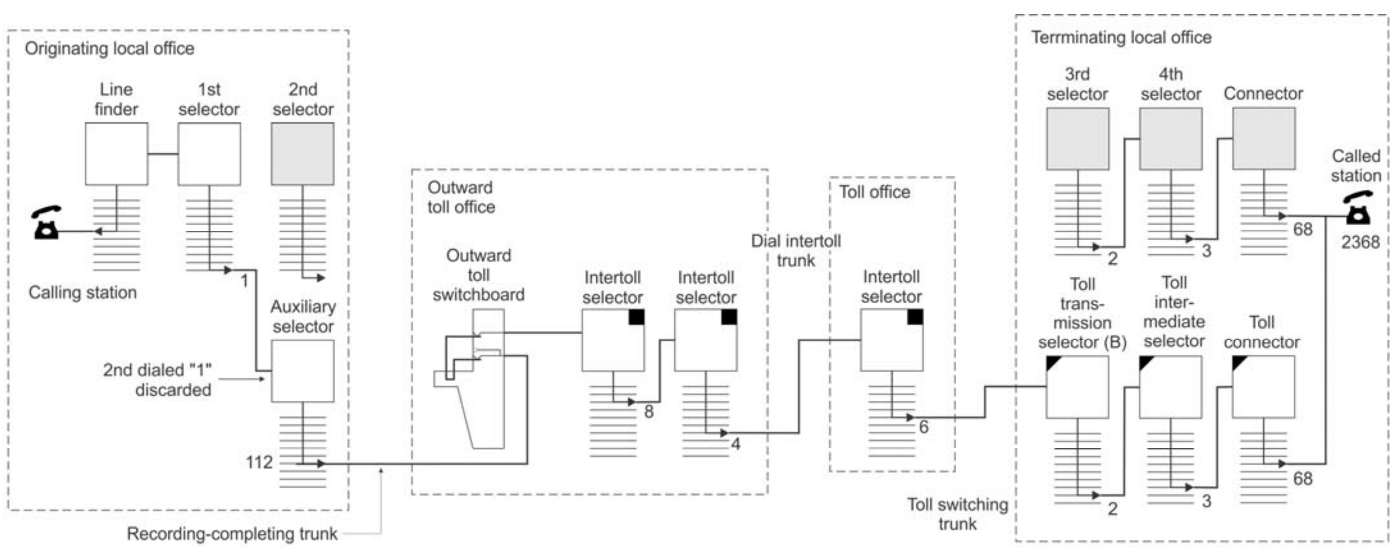

Figure 6. Intertoll dialing

For the most part, the toll train now operates in the same way as was described above.

Here, the outward operator dials a series of arbitrary digits to establish a connection, through SXS switches (*intertoll selectors*), to the toll train at the destination office. The example assumes that there was a direct trunk to the destination toll office. But if no such was available, the operator might have dialed through an intermediate toll office, again using arbitrary digit sequences.

This scheme of setting up the "interior" part of the toll connection (that is, between toll offices) by dialing into switches was known as "intertoll dialing". The switching train used was called the "intertoll train". Later, the trunks between toll offices came to be called "intertoll trunks" (and I will use that term here).

Surprisingly, the signaling and control protocols used in the *intertoll trai*n were quite different from those used in the *toll trains* at the destination local offices. The *toll transmission selector*, the "incoming selector" of the toll train (but in a sense the end of the *intertoll train*), mediated between the two sets of protocols. But the toll transmission selector used in this situation was different in detail from the toll transmission selector seen in figure 5, which had an intimate relationship with the adjacent inward toll switchboard. This kind was accessible by dialed intertoll connections.

Just as I had marked the switches that were part of the *toll trains* with a little triangle, I have marked the switches that were part of the *intertoll train* with little black squares in their upper right corners.

I call attention that the toll transmission selector seen here (labeled "B"—my notation only) is different than that seen in figure 5 (labeled "A"). The "front end" of the "A" kind is arranged for an intimate relationship with a toll switchboard. The front end of the "B" kind is arranged for more generalized access by way of an intertoll trunk.

4 BATTERY FEED FOR TOLL CALLS

4.1 Basic concepts

Here I will return to the matter of battery feed, which has a substantial influence in the way that the toll switching trains of the era assumed in this article arranged and operate.

For reference and comparison, figure 7 shows a typical example of how talking battery is applied to the calling and called line in an SXS local connection. This occurs in the connector.

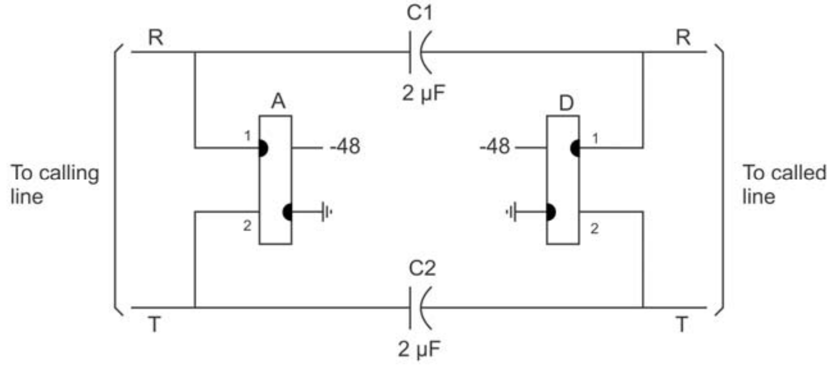

Figure 7. Illustrative local battery feed arrangement

Battery and ground (collectively, "battery") are fed to each line through balanced windings of two relays (here labeled with their typical designations in a local SXS connector). The real purpose of these relays is to determine whether the two lines are on hook or off hook. Thus they are actually *supervisory relays*, but because of the overall purpose of this circuit, they are most often described as "battery feed" relays.

The speech signals are carried between the two lines through coupling capacitors, C1 and C2.

The relay windings have fairly large inductances. Thus they do not "short circuit" the speech signals.

This circuit does not regulate the line current, which varies with line resistance. Thus for a longer line, with a greater resistance, the current is less, and thus the transmitter output is less. But because of the increased loss of a longer station line, this is just the time we would rather not have a lower transmitter output. Still, in local service, even subscribers on longer lines received "acceptable" transmission performance.

But especially in the earlier days of long distance service, where it was difficult to fully overcome the attenuation of the various lines, this shortcoming of the basic SXS battery feed circuits was particularly adverse.

This suggested that when the telephone set was involved in a long distance connection, it was desirable to use a less-primitive battery feed circuit. Figure 8 shows a typical "toll" battery feed arrangement:

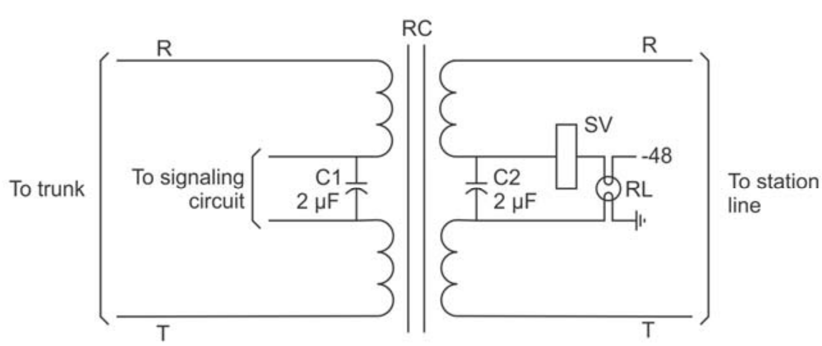

Figure 8. Illustrative toll battery feed arrangement

Here, the line current is regulated by resistance lamp RL. As the current through it increases, the filaments get hotter, and their resistance increases. Thus the current through the lamp remains relatively constant with changes in the resistance of the "load" (in this case, the station sets as seen though their lines).

The coupling of speech circuits across this circuit is done through a *repeat coil*[9] (audio transformer), RC.

Relay SV ("supervisory") has a fairly low resistance. Its purpose is to determine whether there is current flow in the circuit or not, and thus whether the station is on hook or off hook.

Capacitor C2 provides a low impedance path for speech signals, preventing any significant fraction of the speech signal current from passing through SV and RL, where the power it represented would be dissipated and thus lost.

The need to utilize this battery feed arrangement (said to provide "toll grade" battery) leads to a couple of the differences between they way SXS equipment is configured and operated in a local connection and the way it plays one or both of its roles in a toll connection.

4.2 Implementation

Figure 9. shows the same toll connection shown in figure 6 except that the siting of the battery feed to the two stations is now indicated.

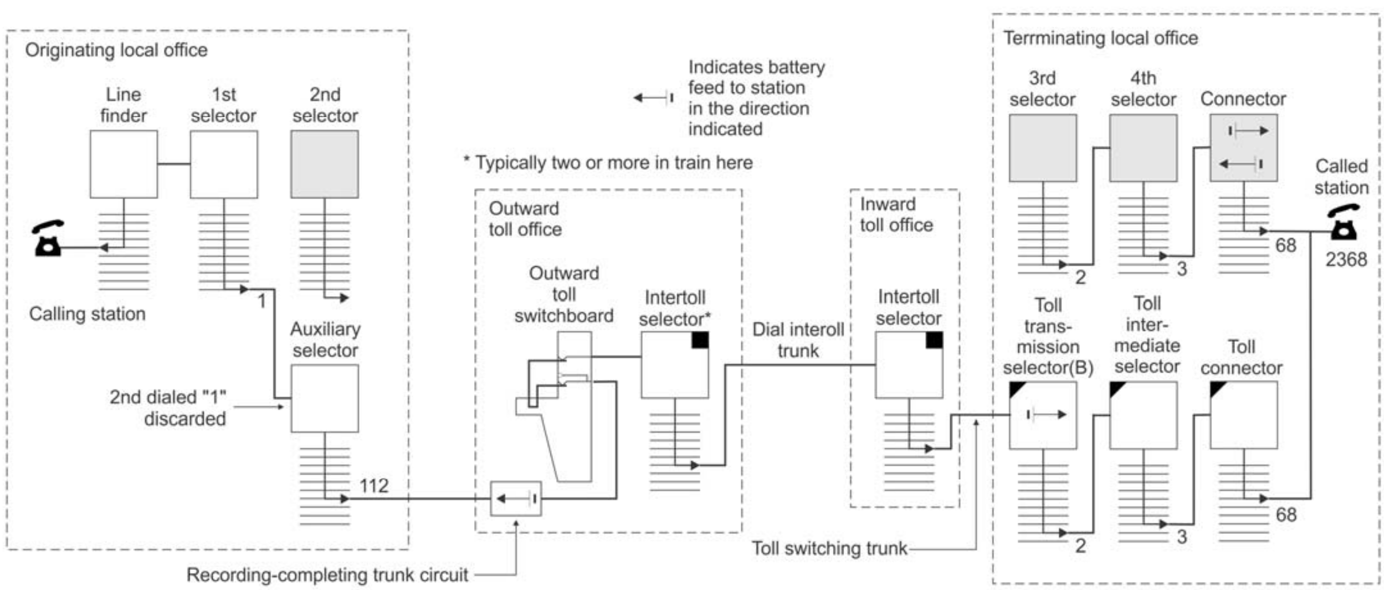

Figure 9. Toll connection showing battery feed to stations

Firstly, for comparison, at the top of the terminating local office we see a reminder of where battery feed is sited in an intraoffice local connection.

In the toll connection, we see that battery is fed to the called station from the *toll transmission selector*. And of course there is a

[9] At first called "repeating coil", since its job was to repeat the speech signal.

transmission coupling path there as well, the main reason for the name of that selector.

We also note that the calling line is fed battery from the recording-completing trunk circuit at the outward toll switchboard.[10] This typically follows the same arrangement seen in figure 8 (aimed in the opposite direction).

There is DC on the conductors of the dial intertoll trunk and toll switching trunk, but it does not have any "transmitter current" implications. Its role is totally for signaling. We will be looking into that in detail in a little bit.

Since in the local train battery is fed to the called line from the connector, why in the toll train is it fed from the toll transmission selector? The reason is that the toll battery feed and transmission circuit is more costly than that in the local connector and takes a lot of space (the repeat coils used at the time were quite large), and there were many more toll connectors than toll transmission selectors. Thus it was more beneficial to locate the more costly circuit in the toll transmission selector.

5 COMBINATION CONNECTORS

It was actually quite common in SXS offices to use *combination connectors*. These could either operate with a local connector "personality" or a toll connector "personality", depending on through which of their two "ports"[11] they were seized by a selector. The concept is shown in figure 10.

---

[10] The odd name of this trunk and its trunk circuit is an artifact of an earlier mode of handling toll calls, with which we will not be bothered in this article.

[11] The term "port" was not actually used in telephone industry practice "in the day", but in a modern context it is well descriptive.

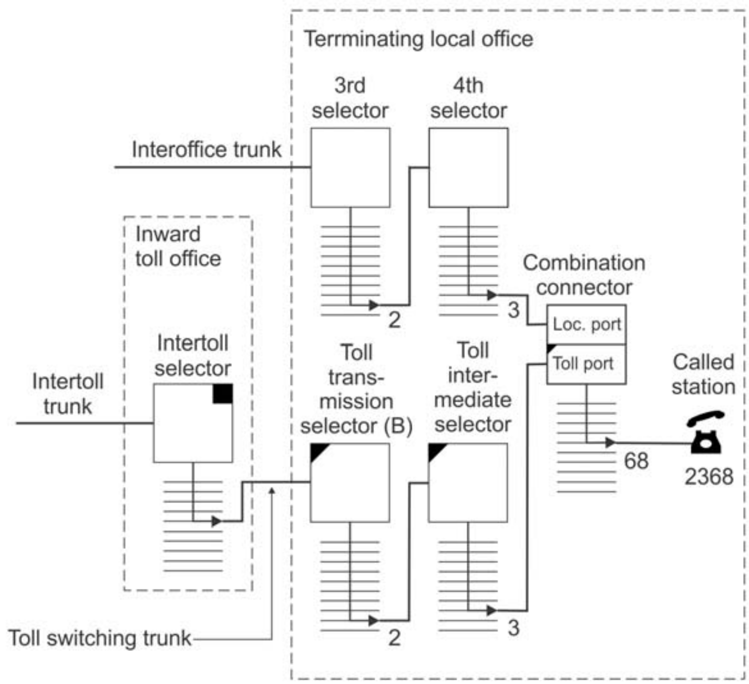

Figure 10. Combination connector

When the switch is seized through either port, it is marked busy at the other port.

The arrangements by which local selectors choose a connector are made so that local selectors will make the subgroup of combination connectors their last choice, thus reserving them, so far as possible, for toll calls.

6 SIGNALING AND CONTROL IN DETAIL

6.1 Introduction

Here, we finally get to the announced topic of this article: the unique signaling and control arrangements involved with toll trains and (differently) intertoll trains.

Each call involves the working of an *intertoll train* and a *toll train*, closely liked together. In this section, I will follow a call through the combined train, with emphasis on the working of the various leads between switching stages.

6.2 Seizure, pulsing, and release in an SXS local train

For comparison and contrast, we recall that in an SXS local train:

- Battery is fed to the rear (perhaps to the calling line If there is no interoffice trunk in that path) by the last switch that is so far part of the connection.

- A selector or connector is seized by there being a “bridge” between the R and T conductors of its “port”.

- Pulsing of a digit (two digits in the case of a connector) into a switch is done by a train of opens in the bridge.

- The connection is held to the rear by the last switch that is so far part of the connection grounding the S lead to the rear. This holds all earlier switches and they pass that ground on to the rear to hold the earlier switches.

- As soon as the connector reaches the called line and if it is found to be idle, ringing is applied automatically by the connector.

- As soon as the called station answers, ringing is stopped (“tripped”) and the battery sent to the rear on the ring and trip is reversed in polarity (“reverse battery answer supervision”). This advises any entity to the rear that the called station is now off hook (assuming that there is some entity that cares; often there isn’t).

- If the called station than goes on hook, the battery to the rear is restored to “normal” polarity. Again, this is to the benefit of any entity to the rear that cares.

- A completed connection is released only when the calling station goes on hook. This is recognized by the connector, which opens the sleeve lead to the rear (releasing the earlier parts of the train) and itself releases.

6.3 The cord circuit supervisory lamp

I will often mention what happens, after a certain event, to the cord circuit supervisory lamp at the outward toll switchboard.

Note that when the operator plugs the cord into the trunk jack to begin setting up the connection, the cord circuit supervisory lamp does not initially light. (This is different from the situation in a local manual switchboard.) The changes I describe are from that initial situation.

6.4 Intrabuilding and interbuilding trunks

In the *toll train*, almost always all the switches are located in the same building. The “trunks” leading from one selector to the next, or to the toll connector, comprise four “local wiring” leads, T, R, S, and C, whose functions will see shortly.

In the *intertoll train*, there are indeed interswitch “trunks” that also run between selectors of successive stages in the same building. These also comprise four “local wiring” leads, T, R, S, and SP (supervisory—we will learn of its function shortly).

But the preponderance of intertoll trunks run between different buildings (to say the least - these trunks may be hundreds, or even thousands, of miles in length).

Such a trunk may be transported by a variety of transmission systems. All these systems (at least as we may find them in this context) provide, in addition to the speech signal transmission path, two two-state signaling channels.

Because one of the classical roles of such generalized signaling channels (in particular, the one that is rearward in a certain situation), was to indicate to a calling operator the *on hook* vs. *off hook* state of the called station, the two states of these generalized signaling channels (in either direction, regardless of the function) are always spoken of as “on hook” and “off hook”.

In order for such a transmission facility to accommodate the control and signaling operations of an intertoll trunk, there must be at each end what I have (for simplicity’s sake) here *called trunk terminating equipment*. Figure 11 shows this.

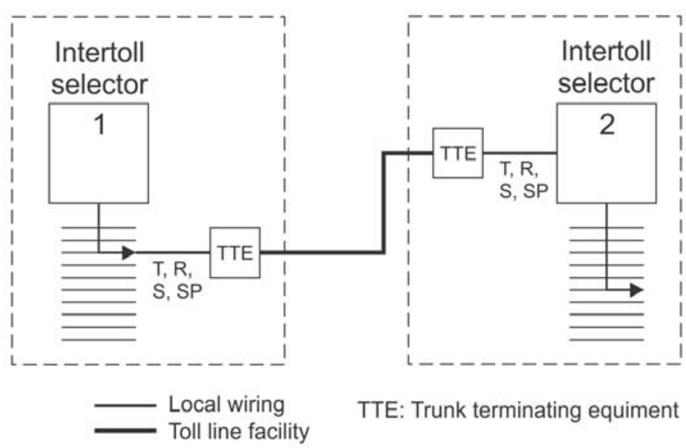

Figure 11. Intertoll train—interbuilding intertoll trunk

One of the jobs of the trunk terminating equipment is to transform the “language” conveyed over the T, R, S, and SP leads into a language that can be conveyed with only a singe two-state signaling channel in each direction and vice versa. We will see this happening as we go.

As I describe the operation of the intertoll train, it will be in terms of as if the trunk were intrabuilding. In a later section I will discuss the implications of the (very important) situation of interbuilding trunks.

6.5 Simplex signaling

In the intertoll train, seizure of a selector (or in fact, of the TTS) is not done by placing a DC "bridge" across the T and R leads. Rather, it is done by essentially grounding both T and R from a DC standpoint. Figure 12 shows the circuit principle involved.

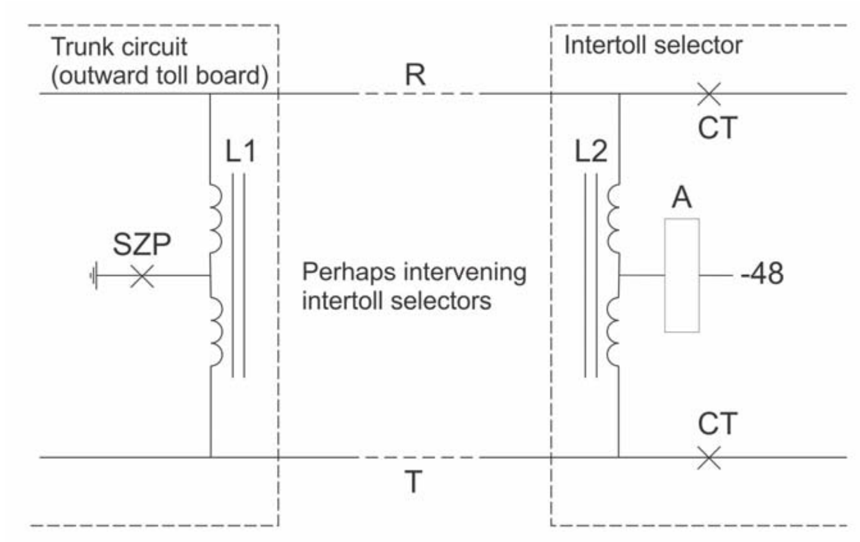

Figure 12. Principle of simplex ground signaling

This is a convention taken from the way signaling states were at one time sent though a long trunk carried by a physical pair, known as "simplex signaling", and that term is used here as well.

Here, we imagine that the seizure of the successive switches of the train, and the pulsing to set those switches, propagates from the outward toll switchboard by way of a trunk circuit.

There, a hypothetical relay contact designated SXP (seizure/pulsing) does this. The ground is applied at the centertap of inductor L1, and thus, from a DC standpoint, is applied to both T and R. The inductance prevents the speech signals that will later appear at this point from being "shorted out" by this DC connection to both T and R.

At the intertoll selector that is currently "at the point of the spear", this simplex ground is "picked up" for its A (seizure and pulsing) relay from the center point of an inductor connected to T and R.

6.6 Intertoll selector operation

6.6.1 *Seizure*

Seizure of the selector is done by a simplex ground, typically originating at the trunk circuit at the outward toll switchboard and perhaps having been passed, transparently, through earlier selectors, which, of course, have cut through.

The simplex ground is accompanied by the sleeve lead being grounded forward by the trunk circuit at the outward toll switchboard. The role of this ground it to "hold" all the switches in the toll connection as it builds up and after it is completed.

The simplex ground operates the A relay. The A relay operates the B relay (slow release) in the familiar way[12]. The B relay grounds the sleeve lead at this selector.[13]

6.6.2 *Pulsing*

Pulsing (sent from the dial at the outward toll switchboard) arrives as periodic removal of the ground from the simplex path. This releases the A relay for each pulse. The entire operation proceeds essentially as for a local selector.

After the dialing of the digits is completed, the switch autonomously steps in the rotary direction, hunting for an idle switch at the next stage at that level.

6.6.3 *No idle following selector found*

If there is no idle next-stage selector on the level indicated by the received dialed digit, the switch continues to step in the rotary direction until it has passed all bank terminals. This operates the *11th step rotary* contact set. One contact there stops the rotary stepping. Another applies ground interrupted at 120 IPM on the rearward SP lead. This is passed by the trunk circuit to the switchboard, which will cause the supervisory lamp of the cord circuit at the outbound toll switchboard to flash, following that pattern, telling the operator that the connection cannot be completed.

6.6.4 *Cut through*

When an idle next-stage selector is found on the dialed level, this selector, via its cut through relay, (CT in figure 12), takes the incoming ring and tip off the simplex inductor and connects them to the switch wipers and thus to the following switch. The A relay releases. Shortly, the B relay releases.

---

[12] In step by step switches, the relays are invariably designated based on their physical location on the switch "chassis", and the designation does not indicate function. But in the vast majority of selectors and connectors, the A relay is the seizure relay and the B relay is its slow release follower. Thus in a generalized discussion, it it common to speak as if those designations imply those functions, and I will generally do so here.

[13] The purpose of this in not clear, given that the sleeve is already grounded from the rear. This is one of the "loose ends" to which I alluded earlier.

The CT relay remains operated as it is held to the sleeve, which is still grounded from earlier in the train, even though the B relay has released and removed the ground it had placed on the sleeve. The CT relay operated prevents the switch from releasing, even though the B relay had released.

6.7 At the toll transmission selector

6.7.1 *Seizure and pulsing*

The end of the intertoll train is a toll transmission selector (TTS). It is also the beginning of the toll train. Seizure and pulsing into that switch work just as described above for intertoll selectors. The remainder of its operation is quite different.

6.7.2 *Cut through*

It there is an idle trunk to the next stage switch (a toll selector), cut through occurs, in this case meaning that a resistive bridge is placed across the T and R leading to the next switch to seize it, in essentially the way that a selector in the local train is seized.[14] However, the sleeve S lead to the next stage is also grounded.

6.7.3 *No idle following selector found*

If there is no idle next-stage selector on the level indicated by the received dialed digit, the switch continues to step in the rotary direction until it has passed all bank terminals. This operates the *11th step rotary* contact set. One contact there stops the rotary stepping. Another applies ground interrupted at 120 IPM through a 500 ohm resistance on the on the rearward R lead.

The TTS converts this to pulses on the rearward SP lead. This passes to the trunk circuit at the outward toll switchboard, which will cause the supervisory lamp of the cord circuit at the outbound toll switchboard to flash, following that pattern, telling the operator that the connection cannot be completed.

6.8 At an intermediate toll selector

If the next switch is a toll selector, when idle it presents battery across the T and R through windings of a A relay (just as in a local selector). When the switch is seized, the resistive bridge across T and R, coming from the TTS, operates the A relay, which operates the B relay (slow release).

---

[14] Note that this is different from what we had in the intertoll portion of the train, where seizure and pulsing was by simplex ground.

Pulsing takes place just as for a local selector, and trunk hunting also operates in essentially the same way.

6.8.1 *No idle following selector found*

If there is no idle next-stage selector on the level indicated by the received dialed digit, the operation is just as described in section ***.

6.8.2 *Cut through*

It there is an idle trunk to the next stage switch (likely a toll connector), cut through occurs, in this case meaning that (just as in a local selector), the T and R are taken off the A relay (which releases) and extended forward through the selector wipers to the following switch. in the toll train). The S lead going to the next switch is also grounded. The cut through relay locks to the S lead.

When the A relay releases, it releases the B relay, which removes the ground the B relay had applied to the S lead. But the S lead is also grounded forward from the TTS, and so the cut through relay stays operated, keeping this selector "up".

6.9 At the toll connector

6.9.1 *Seizure*

When the toll connector is idle it presents battery across the T and R through windings of a A relay (just as in a local connector). When the connection reaches the toll connector, the bridge across T and R (from the TTS), operates the A relay. Here, there is no slow release follower of A (what would often be designated B). But the grounded S also reaches the connector, and will hold it "up" (there being no true equivalent here to the B relay in a local connector to do that).

When the connector is seized, the ring trip relay (will call it "RT"[15]). is operated, and it locks to the C lead, which is grounded at this time (at the connector, where C is for the moment tied to S, and the incoming S is grounded.

Pulsing of two digits follows generally the same concept as for a local connector.

6.9.2 *Called line found*

When the connector arrives at the called line, the connector removes the ground to the rear on the C lead. At the TTS:

---

[15] In fact, in the most common toll connector, it is this relay that is designated "B" (owing to its physical location).

- The ungrounding of the C lead from the connector releases a slow release relay at the TTS. When it releases (after a brief period), the TTS grounds the C lead forward. It is now the TTS that controls the C lead between it and the connector.

- The incoming T and R (likely from an intertoll selector) are connected to one side of a transmission repeat coil (the simplex connection to the A relay of the TTS now being picked up through its windings).

- The resistive bridge across T and R forward is removed.

- The downstream side of the transmission repeat coil (with a battery feed circuit) is connected to the T and R forward.

At the connector, the incoming T and R leads are taken off the seizure relay (A) and extended forward to potentially reach the wipers and thus the called line; that path is, however, not now complete.

6.9.3 *Called line busy*

If the called line was found to be busy, the connector applies ground pulses at 60 IBM to the R lead to the rear. At the TTS, this operates the battery feed relay there on the same pattern. The TTS repeats that pattern rearward as ground pulses on the rearward SP lead. The ultimate result is that the cord supervisory lamp at the outward toll switchboard flashes in that same pattern, advising the operator there that the called line is busy.

6.9.4 *Celled line idle*

At the connector, the incoming T and R leads are extended forward toward the wipers and thence to the called line.

When the connector removed ground from the C lead, the RT relay is released. In its released state, ringing is applied, though the "trip" winding of RT itself (which will detect the flow of DC in the line when the called station answers).

6.9.5 *Answer*

When the called station answers, the ring trip relay, RT, operates, stopping the ringing. It locks operated to the C lead, which is now again grounded (from the TTS). RT also completes the path from the incoming T and R to the wipers (and thence to the called line).

The battery provided by the TTS forward on T and R extends through the toll selectors and, now, through the toll connector to the called line and thence to the called station.

As that station is now by definition off hook, current flows in this path and operates the battery feed relay at the TTS. This causes the TTS to ground the rearward SP lead. As a result, the supervisory lamp in the cord circuit at the outward toll switchboard goes dark.

6.9.6 *Called station goes on hook*

If the called station goes on hook, the current in that path ceases, which causes the release of the supervisory relay at the TTS. The TTS removes the ground from the rearward SP lead. At the outward switchboard, this causes the supervisory lamp to light, alerting the operator than the called station had "hung up".

6.9.7 *Release of the connection*

If the outward operator pulls the cord from the trunk jack, the trunk circuit opens the S lead forward, which releases all the intertoll selectors.

When this process reaches the TTS, the TTS removes the ground from the forward sleeve, releasing any further selectors and the toll connector. And the TTS itself releases. *Finita est*.

7 RERING

In some scenarios, after a toll conversation is competed, the outward operator will need to speak again with the called subscriber.

In such a case, when the outward operator's cord supervisory lamp lights, indicating that the called station has gone on hook, she operates her ringing key for the cord. The result is that the trunk circuit at the switchboard removes from the T and R the simplex ground that is one aspect of the "seizure" signaling.

Of course, before the connection has been set up, such a brief retraction of the seizure signal would be interpreted as a dialed digit of "1". But the TTS knows that we are beyond that phase, and so it responds to that brief interruption by sending an brief open forward on the C lead.

At the connector, this results in the release of the RT relay, which recommences ringing. The rest of the process is just as we saw at the beginning of the call (section 6.9.4 *et seq*).

8 DELAYED RINGING

We saw in section 6.9.4 that once the toll selector has reached the called line and it is idle, ringing starts promptly.

In some scenarios[16] it is desired to make a connection to a line but not start ringing until the toll operator calls for it. In these situations, the path to the toll connector is through a different type of TTS (in fact, the kind I call type "A", as seen in figure 6).

When the toll connector reaches the called line and finds it idle, it (just as we saw above) advises the TTS by removing ground from the rearward C lead.

But, here, rather than the TTS delaying a short while before putting its own ground back on the C lead (which we saw above releases the RT relay at the toll connector and causes ringing to start), this kind of TTS applies its own ground to the C lead "immediately". (There is a very short gap in the ground on the C lead, but the RT relay is slow release and so does not release when this occurs.)

At this time, the TTS advises the calling operator, by a change in supervisory state[17] (lighting the cord supervisory relay for the first time in this kind of call) that the called line is ready to be rung.

When the operator does want the called line rung, she sends ringing signal into the TTS. The TTS then, for a short period, removes ground from the forward C lead for a short time. This releases the RT relay at the toll connector, which starts the ringing of the called, line. The rest of the process proceeds as described above in section 6.9.4.

9 COMBINATION INTERTOLL AND TOLL TRANSMISSION SELECTOR

In some network setups, it is desirable to have the same selector, for some calls, to act like an *intertoll selector* (connecting perhaps to a *toll transmission selector* at the destination office, in another building) and, for other calls, to itself act as a *toll transmission selector*, connecting to toll intermediate selectors in a destination office in the same building. This would allow a smaller number of connectors to be installed for any given combination of local and toll traffic.

Of course, in these two tasks, the technical arrangements are quite different. For example, when acting as a toll transmission selector, the switch must include a battery feed and transmission coupling arrangement; when acting as an intertoll selector, it does not include that, but rather provides a through path for T and R. And there are

[16] Description of the reason for these scenarios, albeit fascinating, is beyond the scope of this article for reasons of conciseness.

[17] The supervisory signaling between the switchboard and an "A" type TTS is a bit tricky, but we need not here be concerned with its electrical details.

differences in the signaling and control protocols on the "downstream" side.

These two personalities can be selectively exhibited by a *combination intertoll and toll transmission selector*. The personality in effect depends on the level to which the selector is dialed, under control of a contact on a *normal post contact assembly*.[18]

This assembly provides for contacts that can be operated when the selector is at any of certain levels (this being done by a sheet metal "cam" having teeth for each level that can be bent out to operate a contact when the switch is at that level).

The details of this creature are beyond the scope of this article.

10 INTERBUILDING INTERTOLL TRUNKS

In section 6.4, I pointed out that when an intertoll trunk traveled between buildings (as most do), the signaling protocol I described, conducted over the four leads T, R, S, and SP must be transformed to a "language" that can be conveyed over a single two state signaling path in each directions.

The table of figure 13 gives a basic description of this transformation. Recall that this pertains to intertoll trunks.

[18] The name comes from the fact that the assembly is mounted on the *normal post* of the switch, a vertical rod whose principal "regular" job is to be the backstop for a lever on the switch shaft so as to establish the "normal" (that is, not rotated) rotary position of the shaft regardless of its vertical position.

Action	Over an intrabuilding trunk (T, R, S, SP)	Over an interbuilding trunk
Seizure	Simplex ground on forward T, R; ground on forward S	Off hook on forward signaling channel
Pulsing	Interruptions of the simplex ground	On hook pulses on forward signaling channel
Called station answers	Ground on rearward SP	Off hook on rearward signaling channel
Called station hangs up	Open on rearward SP	On hook on rearward signaling channel
Rering	Momentary open on forward S	Momentary on hook on forward signaling channel
Release (from operator)	Open on forward S	On hook on forward signaling channel

Figure 13. Signaling transformation for intertoll trunks

11 OPERATION WITH RINGDOWN TRUNKS

11.1 Introduction

In the era in which the long distance network first emerged, the preponderance of cities were served, for local service, by manual switchboard systems. But later, the long distance network as I described it above was predicated on the preponderance of subscribers being served by "dial" local offices. We in particular, because of the context of this article, have generally presumed that the local offices used SXS equipment.

But of course during the era I have presumed there were still many cities still served by manual switching systems.[19] And thus the "switched" toll network had provisions for completing calls to stations in those systems.

11.2 Ringdown trunks

During the early evolution of the telephone network, when all switching was done by manual switchboards, trunks between central

[19] The author had the privilege of attending the dismantlement of the last Bell System manual central office in New Jersey in the mid 1960s.

offices typically were operated on a *ringdown*[20] basis. The operator at the originating office plugged a cord into the jack for the trunk and operated the ringing key for the cord. This sent over the trunk a burst of ringing current, the same as would be used to ring a station on a subscriber line (perhaps 90 V AC at 20 Hz).

This signal was detected at the distant end of the trunk and (in the "modern" form) lit a lamp above the trunk jack, alerting the operator that there was a call coming over the trunk.

In the toll network as I describe it in this article, in many cases, the trunk over which an intertoll switched toll call was taken to a manual local office for completion operating on a ringdown basis.

11.3 Ringdown trunks from an intertoll selector

Assume that the routing of a toll call to a certain manual local office called for a certain intertoll selector seizing a ringdown trunk to that office. Intertoll selectors that may have to do that are augmented by a *selector trunk circuit* just before them (essentially, an "outboard front end" for the selector).

These selectors are equipped with a *normal post contact assembly* (see footnote 20). For the levels on which manual ringdown trunks appear (this selector can in general also access "dial" trunks to dial local offices, on other levels), the normal post contact is operated, and as soon as the selector cuts through to the trunk, it causes ground to be placed on a control lead (RD; you can guess what that means) that runs rearward (along with T, R, S, and SP) to this trunk circuit.

This causes the trunk circuit to send forward (through the selector proper) an approximately two-second long "ringing control signal" (battery through 300 ohms on the SP lead, a forward use of a lead that normally is used in the rearward direction).

At the trunk circuit at the near end of the ringdown trunk proper (the circuit to which the selector actually connects though its wipers), this is converted to the "in the speech band" version of ringing signal that was used on "later" ringdown trunks, typically 135 Hz or 1000 Hz modulated at 20 Hz.

---

[20] The term traces it origin to an early practice in manual switchboards, in which the arrival of ringing voltage (from a line or trunk) operated a relay-like device (a "drop") associated with the line or trunk jack. This caused the release of a little black "flag", which fell down (mind that word) on a hinge, uncovering shiny metal beneath, a visual signal to the operator of a service request (from a line) or call (from a trunk). It was from the behavior of this "flag" that sending ringing voltage over a trunk was spoken of as "ringing **down** the trunk". This then lead to trunks that were operated by sending ringing voltage being called *ringdown* trunks.

12 STOP DIAL OPERATION

12.1 Introduction

We tend to think that, in the SXS system, as soon as one dialed digit is finished (that is, there have been no pulses for long enough that it is clear there will be no more for this digit), the next digit may be dialed.

This is not exactly so. After the digit is dialed into a selector, the selector must hunt along the ten terminals on that level for an idle next stage switch and, finding one, must "cut through" to it. Then the A and then the B relay in that next switch must operate[21] before that switch is prepared to receive that next digit. The basic general network planning specification requires that (when digit pulse trains are sent by a "sender" circuit rather than by a dial) there be a minimum 600 ms interval (the "interdigital time") between the end of the last pulse of one digit and the beginning of the first pulse of the next digit.

But the system design also relies on the assumption that when the pulse trains come from a dial, the human who is dialing (subscriber or operator) takes a while to "wind up" the dial for the next digit, which will (hopefully) in most cases give a sufficient minimum interdigital time. And if a subscriber consistently got wrong numbers, it might have been suggested that he dial at a bit less energetic pace.

12.2 Call to a panel dial office

We have concentrated here on the assumption that the called station is served by an SXS office. But, during the era assumed for most of the article, many larger cities were served by the *panel dial system*, a very complex "common control" switching system.

There, for a call that arrives from a "dial pulse" context, when an incoming trunk is seized, an *incoming sender* must be attached to the trunk to receive the dial pluses. That sender then communicates with the switches in the special way needed to set the switches as indicated by the received dialed digits. Although this actually involves pulses sent back from the switches to the sender (called "revertive pulsing"), it is thought of as the sender "sending" information to the switches[22]. The sender is then detached from the trunk and becomes available for assignment to another incoming call.

---

[21] Actually, the B relay must be operated long enough ("soaked") that its release time will then be as expected.

[22] Thus its name. "Register-sender" would have been more apt, but things are often named based on what is uppermost in the developers' minds at the time. Here, the

The connection of an incoming sender to the trunk takes a little while (and that period can be prolonged if all the incoming senders happen to be already in use on other connections).

Thus if, as soon as a trunk to a panel office is seized, the dialing of digits (in our case, by the outward toll operator) continued without pause, the first few pulses (or even an entire digit or more) might well be lost, and of course the connection will not be (properly) completed.

12.3 Calls to certain community dial offices (CDOs)

A community dial office is a small switching system serving a small community. These were often implemented with SXS equipment, there being certain differences in detail from the SXS systems used in larger central offices.

During the era of interest, some small CDO systems, especially used by not Bell System companies, had a design in which the dialed digits were received by a register, made wholly of relays, which was called into play (from a group of such) when a line wanted service, or when an call came in over a trunk. The register than caused the connection to be made through a switch "matrix" (also made wholly of relays).

Until a register was attached to a trunk to serve an incoming call (and this might take several seconds if all the registers were already busy), any dialed digit pulses would be lost.

12.4 Pulsing control protocols

This is in fact a generalized issue in the telephone network as switching systems (both local and toll) more and more became of the "common control" type, in which incoming digits were always received by a sender or register, which had to be attached to a trunk when it was seized. Accordingly, there arose a set of protocols for what may be called "pulsing control"[23]. All of these protocols incorporated the dogma, "Never pulse into an off hook"[24].

---

scheme used to send information to set the switches was truly unique, and was central to the concept of the panel dial system, so. . .

[23] Actually, it is commonly called "outpulsing control". That is because the sending out of digits from a switching machine (not directly from a dial) is typically said to be "outpulsing" (distinguishing it from the capture of arriving of digits, which however is not called "inpulsing").

[24] There is one obscure exception in a protocol associated with direct distance dialing.

The protocol that pertains to our story here is the *stop dial*[25] protocol. When the setup of the connection reaches a point where the system is not yet ready to receive a digit, the distant entity returns the off hook state on the rearward supervisory signaling channel. The near end knows this can't mean that the called station has answered: the entire number hasn't yet been sent. So it interprets this off hook state as a *stop dial* indication, and it refrains from sending any further digits until the rearward supervisory state returns to on hook.

12.5 In an intertoll selector

In the SXS intertoll train, though, there is a "race condition" problem. Suppose the digit dialed into the selector takes it to a level where there are trunks to a "register-based" system. Once the selector has cut through to the trunk, the panel system will promptly return the off hook *stop dial* signal. (In fact, the trunk will likely return the off hook even when it is not yet seized.) And this stop dial signal will propagate to the toll switchboard, to advise the operator not to dial any more until further notice..

But, after the end of the dialed digit, there is a delay before cut through occurs (while the selector hunts on the dialed level for an idle trunk to the distant system). By this time, the toll operator may well already be winding her dial up for that digit. And some of the pulses of that digit (maybe all of them) will be lost, and the connection will not proceed properly.

Thus, intertoll selectors that might access trunks into panel offices have a special provision. When the switch goes to a level with trunks to a panel office, a contact on the normal post spring assembly is operated.[26] As soon as the digit that had moved the switch to this level is done, this results in an off hook state being sent to the rear by the selector (at this point in the intertoll train, as a ground on the SP lead).

This lights the cord supervisory lamp at the outward toll switchboard, advising the operator, as soon as practical, not to dial further digits until "further notice".

Then, when an idle trunk to the next stage has been found, and the switch cuts through to that trunk, that ground from this selector is

---

[25] Although, as seen from the perspective of the entity that is being dialed into, it would be called the *delay dial* protocol.

[26] A separate one from that used to control automatic ringing for ringdown trunks, a feature that the selector might also have.

removed. But immediately, there will be an off hook state coming from the distant office, so the stop dial indication is continued.

Then, when the distant office is ready for further digits (it having attached an incoming sender), the rearward supervisory state from it is returned to on hook. At the outward toll switchboard, the cord supervisory lamp goes dark, and the operator knows she can resume dialing.

-#-