The Panel Dial Telephone Switching System— Tandem Switching

Douglas A. Kerr

Issue 1
June 15, 2018

ABSTRACT AND INTRODUCTION

The *panel dial* system was a very complex telephone switching system developed by American Telephone and Telegraph company in the 1910s., It came to be the mainstay of the Bell Telephone's System's program, from the 1920s on, of mechanizing telephone service in many of the largest cities in the U.S. and Canada. Prior to mechanization these cities were served by switching systems using large manually-operated switchboards.

Tandem switching refers to the concept that a call from one central office to another is switched at an intermediate switching point, called a *tandem office*. The principal object is greater efficiency in the usage of interoffice trunks.

In the context of the panel dial switching system, two tandem switching schemes were employed, both using the same unique switching mechanism used in the panel dial system itself. This article describes both.

The article begins with a summary of the principle of tandem switching, and then gives a concise description of the panel dial system itself

1 COMPANION ARTICLE

The panel dial system itself is described in some detail in this article. A much more detailed description is given in the article "The Panel Dial Telephone Switching System", by the same author. It is probably available where you got this.

2 TANDEM SWITCHING

2.1 Introduction

In this section, I will introduce the concept of tandem switching in a metropolitan telephone network, and give some insight into the economic advantages it affords.

2.2 A modest metropolitan network

Figure 1 illustrates, geographically, a fictional modest-sized metropolitan area, "Centerville". Its local telephone network comprises 8 central offices. All are "dial" central offices; we may perhaps think in terms of their being panel dial offices.

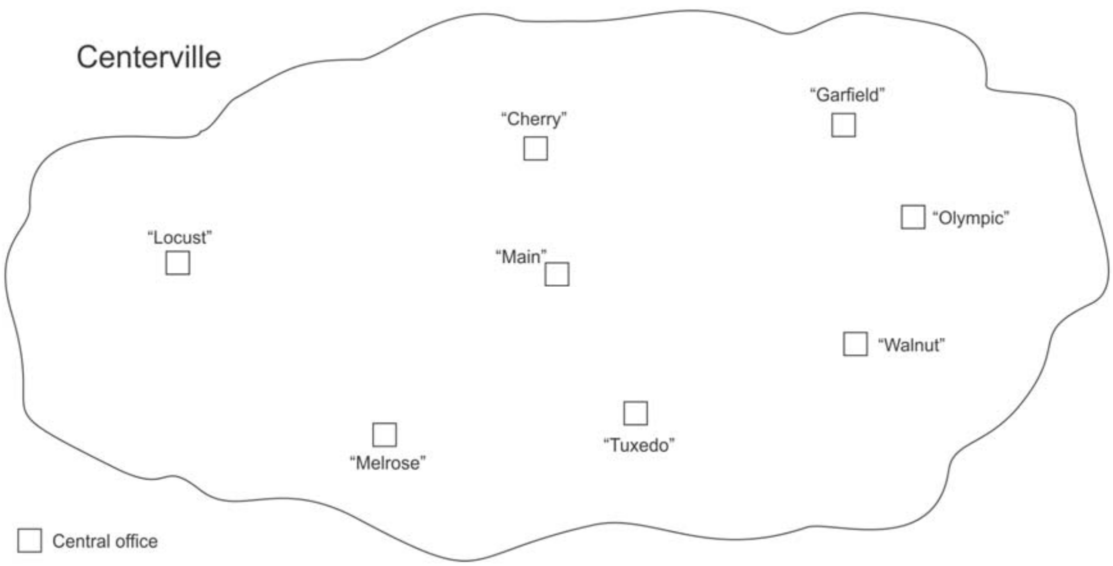

Figure 1. Centerville and its central offices

We of course assume that any subscriber, regardless of the central office by which served, should be able to call (by dialing) any other subscriber in the city, regardless of the central office by which served.

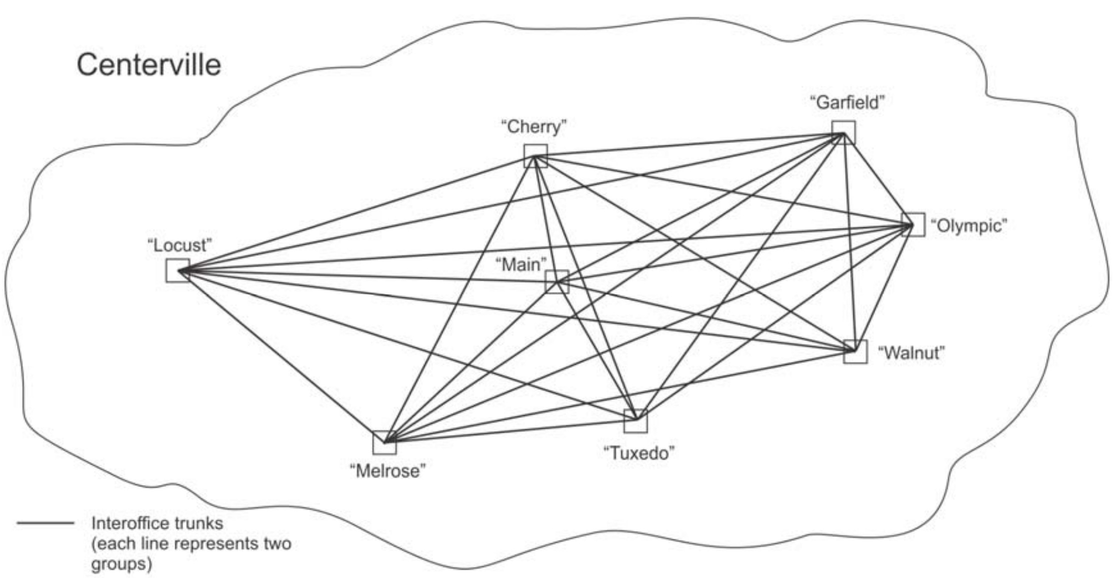

Figure 2. Direct trunking

2.3 Interoffice trunks

To allow this full connectivity, the classical way is to provide groups of *interoffice trunks* between each pair of central offices, as shown in figure 2.

Each interoffice trunk, at any given time, can participate in one connection from its originating office to its terminating office, for example for a call from a subscriber in the Locust central office to a subscriber in the Garfield office, which passes over a Locust-Garfield trunk.

For most of the earlier switching systems (and certainly for the panel dial system) interoffice trunks were "one way"; that is, a trunk that could carry a connection from the Locust office to the Garfield office could not be used for a call by a Garfield subscriber to a Locust subscriber. Thus each line on the figure actually represents two separate groups of trunks, one operating in each direction between the pair of offices shown joined.

Of course the lines that represent the trunk groups are "schematic". They give no hint as to the actual physical route of the cables carrying the pairs that implement the trunks. It might even be, for example, that the trunks from the Locust office to the Tuxedo office would physically travel to the Melrose office (in the same cable as the Locust-Melrose trunks) and there would be "statically" connected to pairs in the cable that carries the Melrose-Tuxedo trunks.

2.4 Traffic engineering considerations

A major issue in the implementation of this network of trunks is how many trunks should be implemented in each group. Typically this is decided based on traffic engineering considerations. It might be that the number to be provided in each group will be sufficient that, during the busiest hour of the day, with the "expected" pattern of calls (we actually say "call attempts", for a reason that will shortly be obvious), the probability that a call attempt cannot be served, because all trunks to the destination office are already busy) will not be over a certain value. A target maximum probability of "call blocking" of 0.01 is a common "bogey".

Now, using one "model" of traffic[1], with a call blocking "bogey" of 0.01, a group of 10 trunks could handle about 4.5 erlangs of traffic (an erlang amounts to one continuous call). With that same model, a group of 20 trunks could handle 13 erlangs, more than twice the capacity of a group of 10 trunks,

---

[1] The "Erlang B" model.

If we look at, over the busiest hour, the fraction of the time that a given trunk would be expected to be in a connection (its *occupancy*—a measure of the "productivity" of the trunk), we would find that for the 10 trunk group that would be 0.45. That is perhaps startlingly low. But that is the "price" of having a 99% probability that an offered call requiring a trunk in that group could be handled.

But for the 20 trunk group the mean occupancy would be 0.65. Each trunk is substantially "more productive" than in the earlier case where only 10 trunks are required to meet the blocking "bogey". This is a classical example of "economy of scale".

In the trunk configuration seen in figure 2, this statistical determination must be made separately for each group of trunks.

2.5 The tandem switching concept

Now the thought begins to emerge that if we could somehow consolidate, say, the Locust-Melrose, Locust-Main, and Locust-Tuxedo traffic and handle it all over one group of trunks, the total number of trunks required would be less than the total of the required number of Locust-Melrose, Locust-Main, and Locust-Tuxedo trunks under the plan of figure 2. We in fact can do that, by way of the concept of *tandem switching*. We see its application to the Centerville network in figure 3.

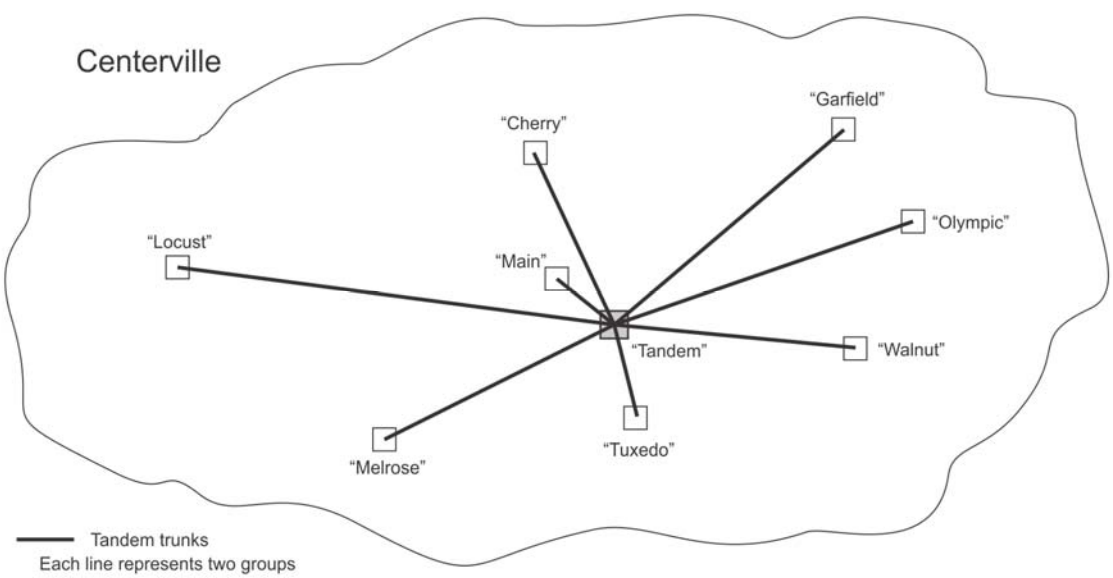

Figure 3. Tandem trunking

Here, we have introduced a new central office with a new role, an intermediate switching point for connections between various "local" central offices. It is identified on the figure just as the "Tandem" office (more about that name in a little while). It has no name in the sense of a component of a telephone number; it serves no subscribers directly.

In the example, for a call from the Locust office to the Melrose office, the call goes over a tandem trunk to the Tandem office, where it is switched to a *tandem completing trunk* to the Melrose office.

For a call from the Locust office to the Garfield office, the call goes over a tandem trunk to the Tandem office, where it is switched to a tandem trunk to the Garfield office.

We thus have all traffic from the Locust office to other offices consolidated, handled over a single group of trunks (Locust-Tandem). The total number of trunks in that group to attain the 0.01 probability of a call being blocked is surely less than the total number of trunks required, under that same call blocking "bogey", under the "direct trunking" configuration seen in figure 2.

This consolidation of traffic has brought us the "economy of scale" mentioned in section 2.4.

What about the term "tandem"? When this *modus operandi* was first introduced, it was noted that here for a call between two central offices the call was not (with respect to its reaching the destination office) switched once (at the originating office) but rather twice (once at the originating office and again at an intermediate office). This was reasonably thought of as *tandem switching* (one switching event and then another). From that, the intermediate switching office became known as a *tandem office*, and the trunks to it as *tandem trunks* (and the trunks from it, *tandem completing trunks*).

2.6 No free lunch

The cost advantage (in terms of trunk efficiency) brought about by this "economy of scale" is, however, counterbalanced by other factors, including:

- There are now two trunks involved in every interoffice call, and trunks cost both "by the each" and "by the mile". With the tandem scheme, a Garfield-Olympic call now uses two trunks rather than one, with a total length substantially greater than the "direct" Garfield-Olympic trunk that was seen in figure 2.

- The tandem office itself is a costly switching machine housed in a costly building of its own or (more commonly) housed in the same building as one of the "local" central offices (and of course that space "costs" as well).

2.7 A hybrid approach

A "hybrid" approach, seen in figure 4, plays off these countervailing costs to provide somewhat an optimum *modus operandi*.

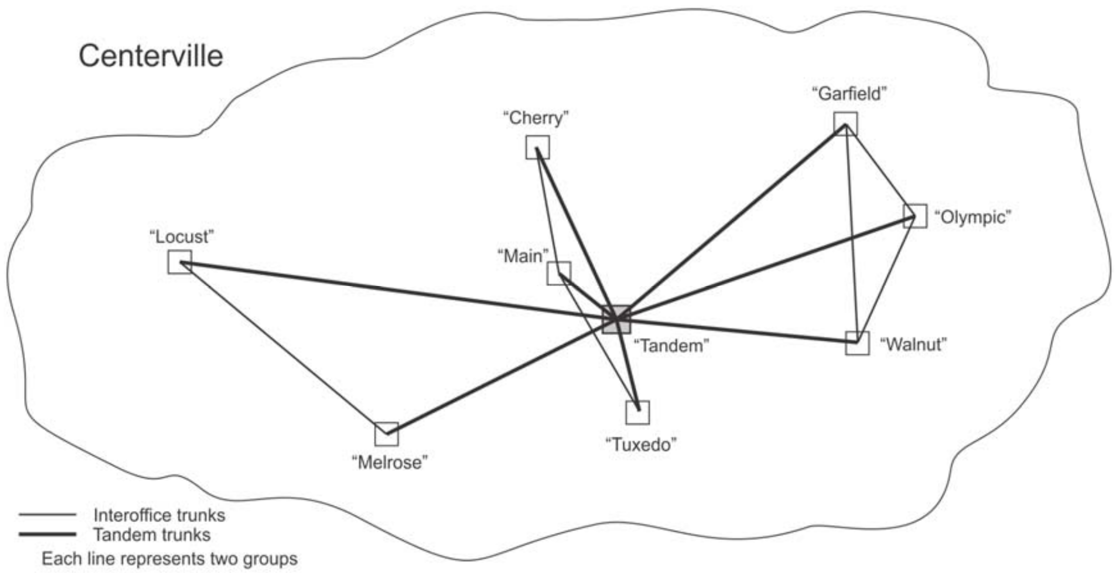

Figure 4. Direct/tandem trunking

Here, for calls from an office to another nearby office, direct trunk groups are provided. These have a modest cost because of their relatively short length. In any case, for social reasons, the traffic to a nearby office will generally be greater than that to a more distant office, and so in these trunk groups we attain some economy of scale.

But calls to the more distant offices are handled through the tandem office, which provides the optimal cost model for such traffic.

2.8 An even better scheme

An improvement on this scheme provides ever better economy. But the panel dial system cannot practice it. I will mention it here briefly only for completeness. We can follow the action on figure 4.

For example, at the Locust office, if a call is placed to a number served by the Melrose office, the Locust switching system will route it over a direct trunk, **unless all direct trunks to the Melrose office are already busy**. Then, instead, it will route the call via the tandem office.

In planning this scheme, the number of trunks in the direct Locust-Melrose trunk group is predicated on a higher probability of blocking, perhaps 0.03. That of course leads to a smaller number of trunks than if we designed that group for a blocking probability of 0.01. (Perhaps only 15 trunks are required rather than 20.)

The result is that the direct trunks are "doing useful work" a higher fraction of the time than if enough had been provided to give an 0.01 probability of blocking. Then price for that is a significant probability that there will not be a direct trunk available. But that is not a problem to the caller; in such a case, the call is "alternate routed" via the tandem office, for which typically a blocking probability of only 0.01 wall be encountered. Thus indeed the probability that a call will be blocked is about 0.01.

3 The panel dial system

3.1 Introduction

Of course, “our” player in this game is the *panel dial* switching system. Here I review its architecture and method of operation.

3.2 Historical context

The system was developed by American Telephone and Telegraph company (the portion that later would become part of Bell Telephone Laboratories) in the 1910s. It was the centerpiece of the Bell Telephone System’s program of converting large metropolitan areas’ telephone service from manual switching to machine switching (*i.e.*, “dial”) operation. It was extraordinarily complicated and sophisticated.

3.3 The panel selectors

3.3.1 *Introduction*

The panel system revolves around a unique type of motor-driven selector. Each selector’s moving part (the *selector rod,* sometimes called an “elevator rod”) moves only along one axis, vertically. The terminals to which it can make contact are made in large unitary “panels” (hence the name of the system), which in most cases can be accessed by up to 30 selectors on one face and 30 more on the other face.

3.3.2 *The banks*

In most of the selectors, there are 500 terminals that can be accessed. But these are arranged in five separate “banks” (each a unitary “panel”) with 100 terminals (at each selector rod’s position) each. The travel of the selector rod is only over 100 positions.

We see one bank (and its construction) in figure 5.

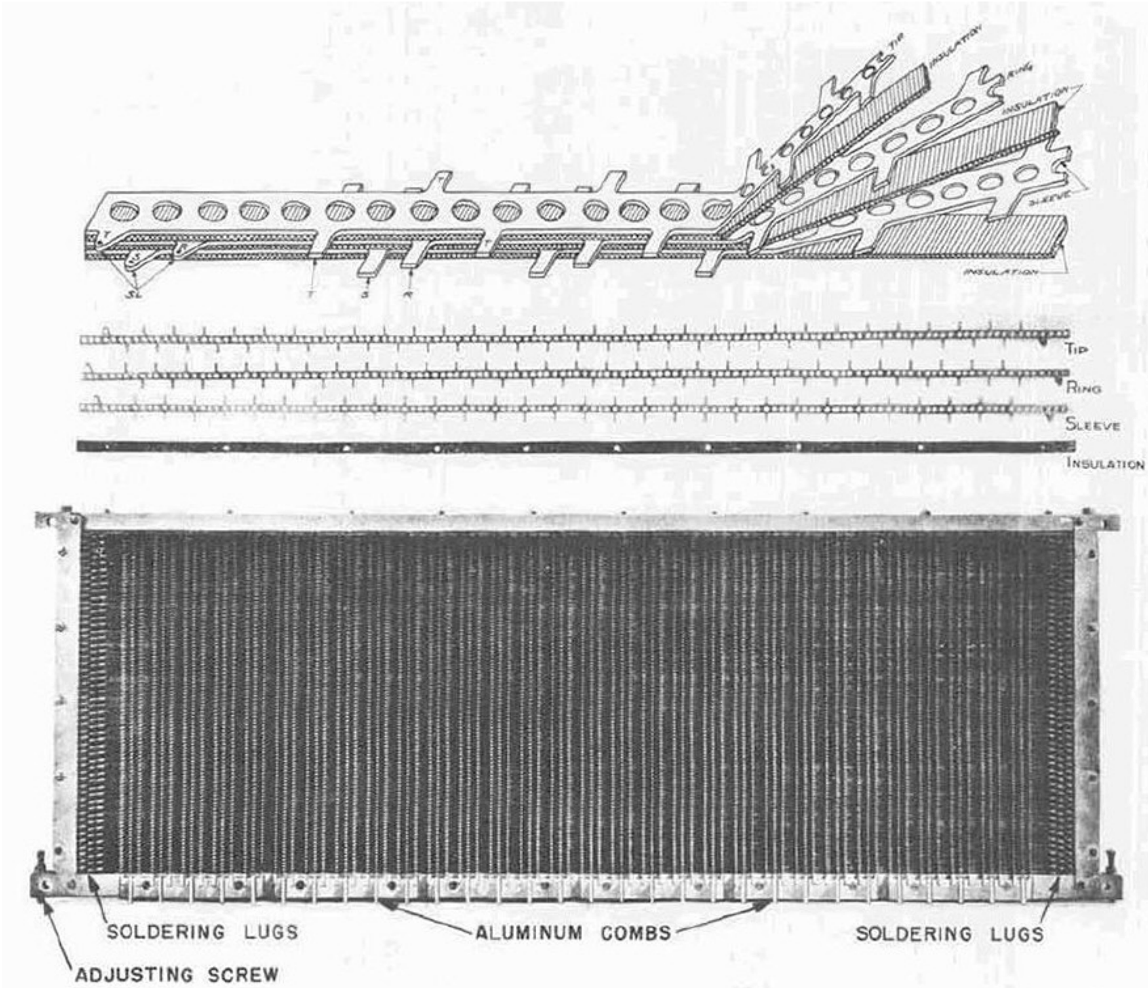

Figure 5. Typical panel bank

The little tabs extending (in both directions) are the “terminal contacts” to which the selector brushes (for selectors on both faces of the frame) make contact. For this bank, there are three contacts at each terminal position, one for each of three leads of the circuit. On the line finder frame banks there are four contacts for each terminal.

3.3.3 *The selector drive*

The rod is raised (and later, lowered) by means of an electromagnetically-operated “pinch roller” pressing a flat strip of spring brass extending from the bottom of the rod against one of two motor-driven, continuously-rotating rollers, faced with a cork friction surface. Figure 6 shows the principle.

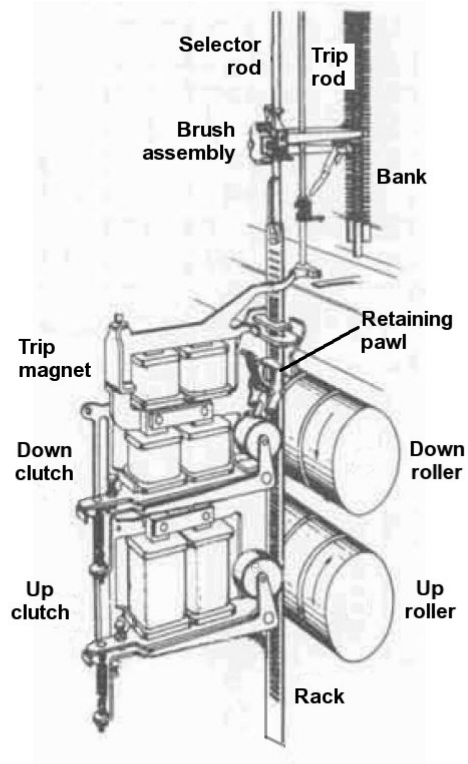

Figure 6. Selector drive system

3.3.4 *Brush assemblies*

Each rod is equipped with five *brush assemblies*. These carry the brushes (wipers) that make contact with the terminal contacts. One brush assembly travels over each bank.

On any given active selector rod, all but one of these brush assemblies have their contact brushes retracted so they do not make contact with the terminal contacts.

Thus, for a terminal to access one of the 500 terminals, the brush assembly for the bank in which that terminal exists is "tripped" so its brushes (alone) can make contact with the terminal contacts. Then the rod is moved to the proper one of its 100 possible contacting positions. The result is that contact is made with the contacts of the proper terminal out of 500 possibilities.

The desired brush is tripped by first moving the selector rod to one of five positions, all before the actual bank terminals could be contacted. Then a trip rod, behind the selector rod, is rotated by a magnet on the clutch magnet assembly.

There is a finger assembly on the trip rod for every brush assembly. These are staggered, so that for any one of the five preliminary selector rod positions, as the trip rod rotates, one of them will engage a trip lever on the brush assembly, while the other four will swing past, above or below "their" brush assembly's trip lever, and miss "catching" it. Then the selector rod is started again on its upward motion. The trip lever that was caught by a trip finger will be "pulled down" (relative to the brush assembly), and that will drop the brushes on that brush assembly (only) so they will make contact with the terminal contacts on its bank.

3.4 The commutator

One need here is to a path from the selector brushes on the movable selector rod back to *terra firma*. This is done by a component called the *commutator*, which is mounted on the frame at the top just above each selector rod. We see an example in figure 7.

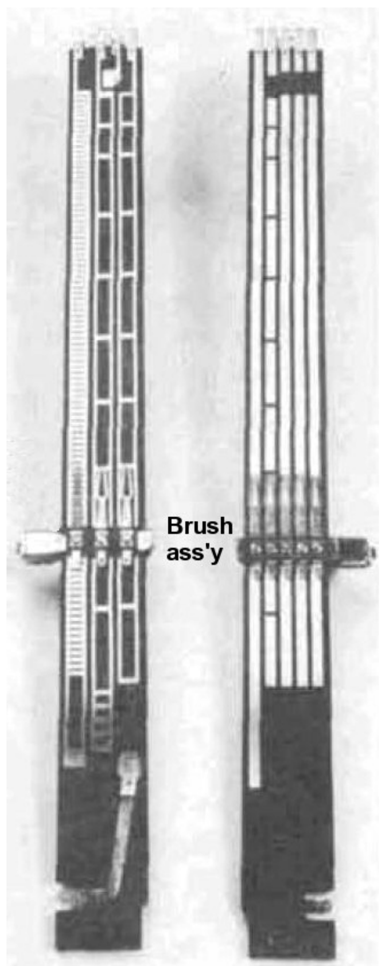

Figure 7. Commutator and commutator brush assembly

We can think of one aspect of this as being like a set of "slip rings", except of course they are straight. Each lead from the brush assemblies (all five assemblies in parallel) goes to a contact brush on a *commutator brush assembly* mounted at almost the very top of the selector rod. (Recall that the selector rod is in fact a tube, so those leads travel inside it, coming out its top and connecting to the brushes.)

These brushes ride on conducting tracks in the commutator that run essentially the entire length of travel of the brush assembly. These carry the brush leads electrically to the selector circuit in "*terra firma*".

In the figure, the brush assembly is shown where it would be with the selector rod about 20% of its way "to the top".

But the commutator performs another kind of function. In addition to the tracks carrying the brush leads, there are other conductive tracks on the commutator that have various conducting patterns on them.

Brushes on the commutator brush assembly, not connected to anything moving but just to each other, ride on these tracks. The result is that electrical conductivity is provided between these tracks or not depending on the position of the selector rod and the patterns of the tracks. The roles these play in system operation will be discussed later.

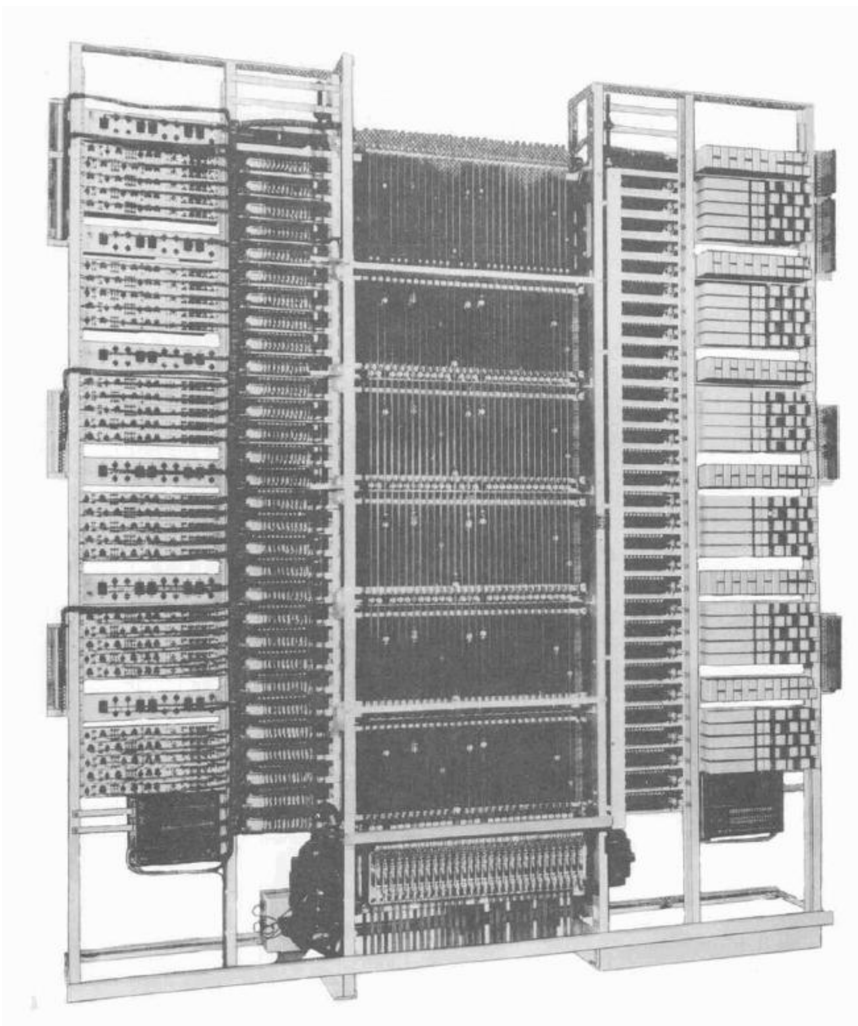

Figure 8. Typical panel dial system selector frame

3.5 Typical selector frame

In figure 8, we see a typical panel dial system selector frame, in this case a district frame. In this example all 30 possible selector positions on each side are populated.

In the center is the selector portion proper. At its bottom we see the clutch assemblies. Above, we see the five banks. At the very top, we see the commutators. To the right of the selector area we see a series of *sequence switches*, one for each of the 30 selectors on this side of the frame. These are power-driven rotary switches that sequentially establish the many "states" of a selector as it does its job.

Further to the right we see relays and transmission apparatus associated with the 30 selectors.

To the left we can see the wiring on the back of the sequence switches and the relays and other circuit apparatus for the 30 selectors that run on the other side of the banks; the frame is wholly symmetrical.

3.6 The common control concept

The step by step (Strowger) telephone switching system, very widely used outside the Bell Telephone System, and widely used in the Bell system in smaller cities, is classified as a *direct progressive* system. "Direct" means that the switches, which are stepping switches, are directly moved by the pulses sent by the subscriber's dial. So when the subscriber dials "3" as a digit of the wanted telephone number, each of the three pulses sent by the dial to convey that digit's value steps the switch up by one "notch", and it finds itself on "level 3".

"Progressive" means that each digit of the dialed number moves a successive switch in the buildup of the entire connection (the exception being that the last two digits set the last switch in the connection). So if the subscriber dials 5212368, the "5" moves a switch in the first stage of the network to its 5th level, which extends the connection to an appropriate switch in the next stage of the network. The pulses for the next digit, "2", go to that switch, and move it to its 2nd level. And so forth.

In contrast, the panel system is classified as a *common control* system. There, the entire dialed number is received and recorded by an equipment unit that is not part of any of the switches, and in fact is taken from a "pool" of them just long enough for it to attend to the establishment of one connection.

That unit then sends, to the various switches along the connection as it is built up, stage by stage, the instructions for setting each of them to the desired position, using a coding system that is entirely different in concept from the trains of pulses, coming from the subscriber's dial, that set the switches in the step by step system.

3.7 Switching machine architecture

Figure 9 shows the overall architecture of a typical panel switching machine (of the "fully mature" configuration—1928 onward):

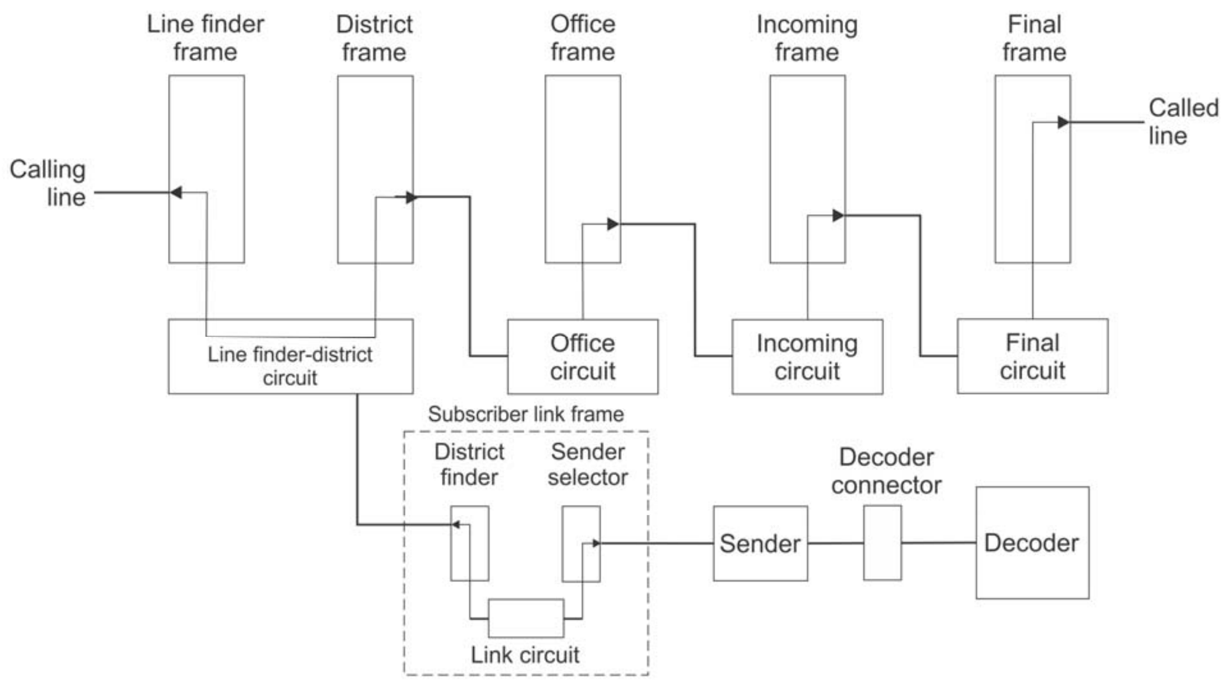

Figure 9. Typical panel system architecture

The actual switch train comprises the five frames shown at the top. The items at the bottom are "common control" equipment.

3.8 Basics of call setup

The first stage of the switch network consists of essentially permanently paired *line finders* and *district selectors*. The task of the line finder is to give a calling line access to the switching network, in the form of a district selector.

Suppose that a subscriber takes his station off hook to place a call. Just as in the manual system, the *line relay* in the line's *line circuit* (not shown in the figure) detects this. Through some complex control circuitry (also not shown), an idle line finder-district selector pair is chosen for this call and the line finder connects to the line

Also, an idle *sender* (more about its name in a minute) is chosen and, through a little double-ended switching network using panel selectors, it is connected to our line finder-district circuit. It is the sender that gives the calling subscriber dial tone, and all the digits dialed by the subscriber are received by and stored in the sender. (Makes you wonder about its name, doesn't it. But be patient.) There are typically over 100 senders in an office.

Now, after an exceedingly important operation that I will ignore for now, the sender "sends forward" (aha!) the numerical instructions for setting "our" district selector. The result is now that the nascent connection is extended to a certain *office selector*.

Then the sender sends, through the connection as it so far exists, to that office selector, the numerical instructions for setting that selector. The result is that the nascent connection is then extended to a certain *incoming selector*. Then the sender sends to that incoming selector the numerical instructions for setting it. The result is that the nascent connection is now extended to the appropriate final selector.

Now the sender sends, over the connection as it is so far built up, to the final selector, the numerical instructions for setting it. The result is that the connection, now complete, is extended to the desired called line. The ringing signal is applied (don't worry just now about who dies that) and we are on the way.

3.9 Translation of the office code

The up to 10,000 telephone lines/numbers that can be reached through a fully fleshed out panel office are placed on the final frames in a logical way such that the numerical instructions for setting the incoming frame and then the final frame can be derived via a fixed algorithm from the four digits of the "line number", and that algorithm is "hard wired" into every sender.

But the trunks to various central offices (including our own) are not placed on the office frames in a way that is directly relatable to the 3 digits of the dialed office code (in a large city; 2 digits in a smaller city for many years). That situation allows great and very beneficial advantages in configuring the resources of a panel office to best meet the requirements for handling the expected traffic over the various paths.

But to get that benefit, each sender must have access to what amounts to a gigantic lookup table, entered with the dialed central office code as the "address", the "return" from which is a set of all the numerical parameters needed to set the district and office selectors in the connection to reach that central office.

That "table lookup" process, from the 1928 vintage of the panel system onward, was done by common control equipment units called *decoders*. It only took one of these about 300 ms to do the translation for one call, and any sender could access any decoder that was not now in use (and there was a sophisticated queuing system), so in fact even a rather busy central office might only need 3 decoders altogether (and the system design imposed a limit of 6).

We see this arrangement toward the bottom of the figure. The decoder connector is a little switching network, made up wholly of relays, through which a sender, with the dialed office code digits in hand, could connect to any of the decoders that was available at the time (or wait for one) to get that translated into a slate of selector setting parameters.

A total of 50 leads is carried between the sender and the decoder, so the input office code and all the "returns" are carried in parallel. To this end, the relays that make up the decoder connectors are a multi-contact type initially developed just for this and related purposes in the panel system. No, decoder connectors are not quiet. They go steadily bang-bang-bang during times of heavy traffic.

The "lookup table" proper, a full copy of which is in each decoder, is "populated" by way of cross-connections on a large terminal field in the decoder frame.

3.10 Revertive pulsing

3.10.1 *Introduction*

So far I have dodged discussion of in what fashion does the sender send forward the numerical parameters that define how each selector along the trail should be sent. It is a rather unique system, called *revertive pulsing*.

The concept can best be explained with a parable. Alice wants to direct Bob to climb up a latter to a certain point, 4 rungs up from the ground, where she knows he will have to be to do something she wants done (perhaps put in a nail on which the hang a picture).

She says "start". Bob starts climbing, and each time he gets to a new rung he says "mark". After Alice has heard "mark" four times, she says "stop". Bob stops, and is on rung 4, just as desired

So the actual numeric parameter of Bob's climb, "4", is conveyed in the **reverse** direction (by four consecutive cries of "mark"). His utterances have "reverted" to the "commanding" end of the communication channel.

3.10.2 *The fundamental circuit*

Fundamental circuit refers to a two-wire path (tip and ring) that starts at the sender, passes through the sender link to the district circuit, and from there grows forward, one stage at a time, as each switch in the train is set. It is over this circuit, out to the switch to which it has so far been "assembled", over which the sender sets that switch.

After all switches have been set, the part of it from the district circuit forward metamorphoses into the actual "connection".

3.10.3 *Principle of operation*

Now let's see, in figure 10, how this really happens, electromechanically.

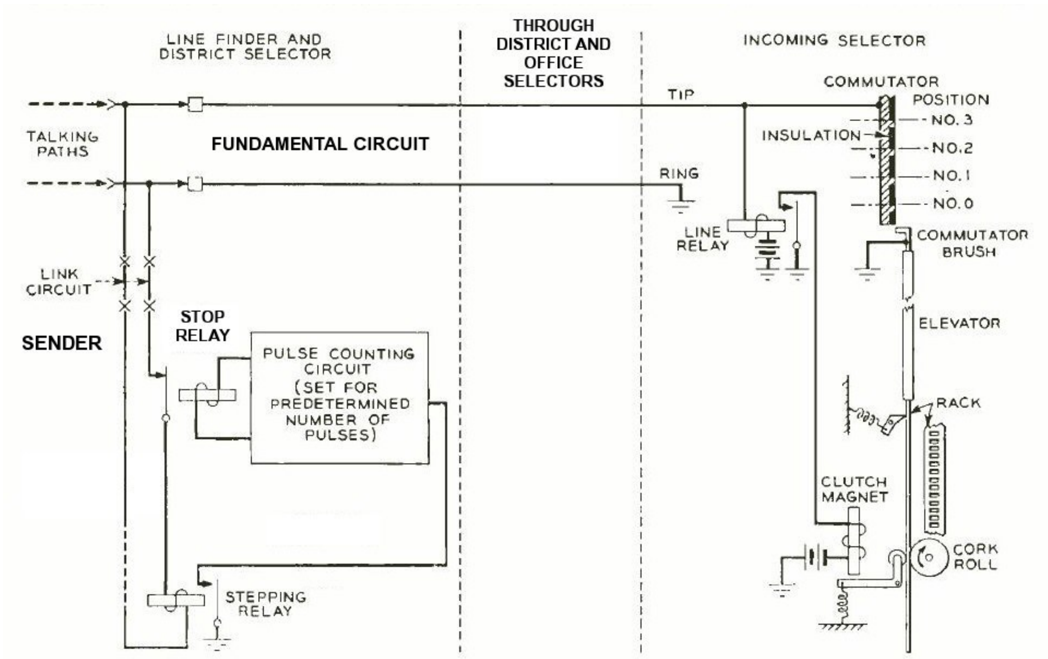

Figure 10. Revertive pulsing

On the left toward the top we see the line finder-district selector circuit. On the lower left we see the sender, attached (for the duration of its work) to the line finder-district selector circuit through the link circuit. On the right we see the incoming selector being controlled. The fundamental circuit has been extended to it through our district selector and an office selector (both having already been "set" as required, using the very scheme we are about to see for the incoming selector).

We will assume that we are in the first stage of control of the incoming selector, needing to move it to one of five positions so that the proper brush can be tripped.

The incoming selector, when idle, maintains ground on its incoming ring lead and battery through the winding of its line relay on the tip lead.

When the connection has been made through the district and office selectors to this incoming selector, there is continuity from tip to ring in the sender (through the coil of the stepping relay in the sender).

The current that flows operates the stepping relay in the sender and the line relay in the incoming selector. At the sender, this tells the sender circuitry that indeed it is now connected to a selector (which it presumes to be an incoming selector, owing to where the sender is in its overall scenario). At the incoming selector, the line relay operates the up clutch magnet, and the selector rod begins to rise.

As it does, a grounded brush on the commutator wiper assembly travels over a region of the commutator in which there are periodic narrow contacts, separated by insulating regions. When the selector rod reaches its first step position (called “position 0”) the wiper makes contact with the first of these conducting places on the commutator, which grounds the tip conductor of the incoming circuit.

That causes no change at the incoming selector end; the line relay remains operated (in fact, the current through it increases). But to the sender, the fundamental circuit is “short circuited”, and current flow through the stepping relay ceases. That causes the counting circuit (composed of a bunch of relays) to say, in effect, “that’s one”. Then the brush moves off the first conducting place, the ground on the tip is removed, and there is again current through the fundamental circuit to the stepping relay (“and-a”).

This process repeats until the counting circuit says, when the count reaches the target location of the distant selector, “that’s it”, which it does by operating the stop relay.

Now, when the brush moves beyond this conducting place, removing the ground from the tip, there now no longer a path through the fundamental circuit and the sender, and so the line relay at the incoming selector releases, releasing the up clutch magnet, and stopping the motion of the selector. The selector drive rack settles back on the retaining pawl, and this stage of the movement of the selector rod is done.

We will see a little later what is the overall sequence of “instructions” issued by the sender in this way to set all the selectors in the connection path.

3.10.4 *Pulse rate*

The rate of the pulses in one revertive pulsing train varies with the specific “setting” command that is being conveyed. The fastest rate is about 32 pulses per second.

3.11 Interoffice calls

What we have seen so far pertains only to *intra-office calls*: those from a subscriber in one central office to another subscriber in the same office. In figure 11 we see the basic arrangement for an interoffice call: a call to a subscriber in a different central office. For conciseness, I have identified the different central offices by their office code (*e.g.*, 521) rather than their names (*e.g.*, Lakeside).

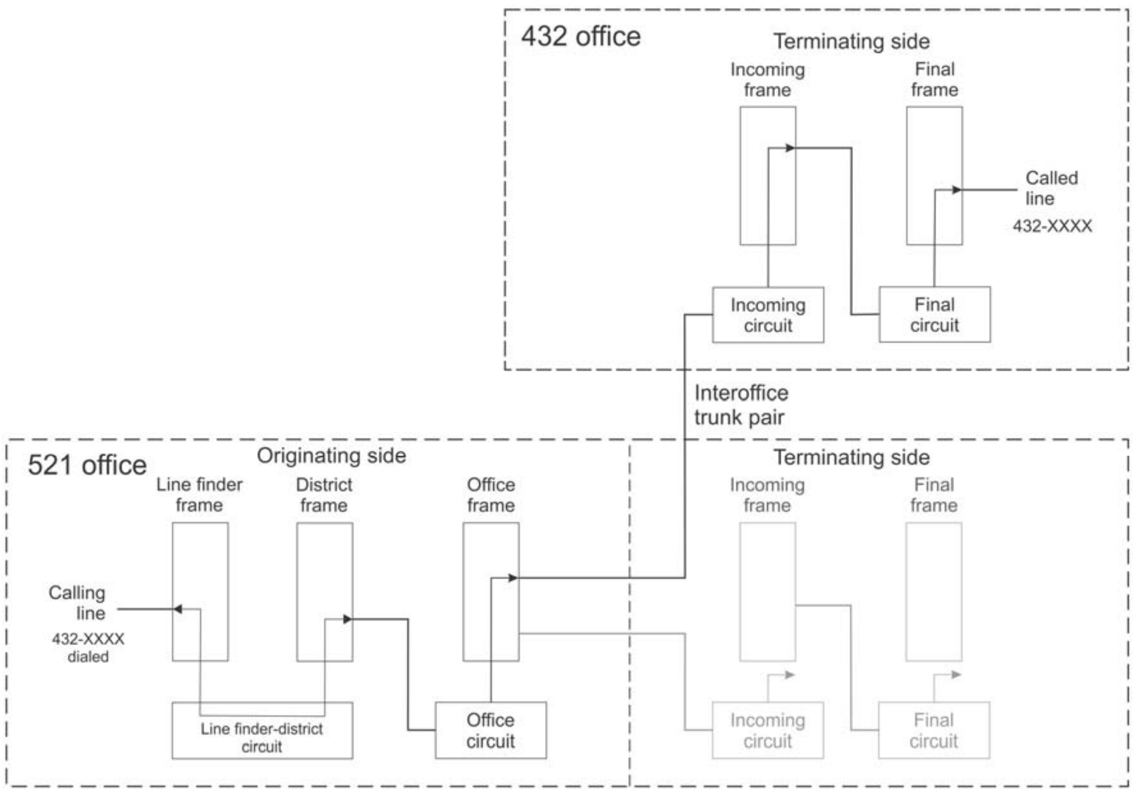

Figure 11. Basic interoffice call

The arrangement is a seemingly almost trivial rearrangement from that for an intraoffice call. The only difference is that now the incoming and final frames are in different central offices. We now see the rationale for the name of the *office* and *incoming* frames. And we can now recognize that "our" panel office can be thought of as having two "sides", the *originating side* and the *terminating side*. In the earlier drawing we could not fully recognize this.

The *district frame*'s name was apparently coined since a "district" sounds like a place where there might be a number of central offices. But there is no relationship between a certain district frame and any geographical area of the city or administrative division of the telephone company. Its name is metaphorical.

Now, in figure 12 we compete the picture by showing as well the arrangement for a call from a different central office to "our" central office.

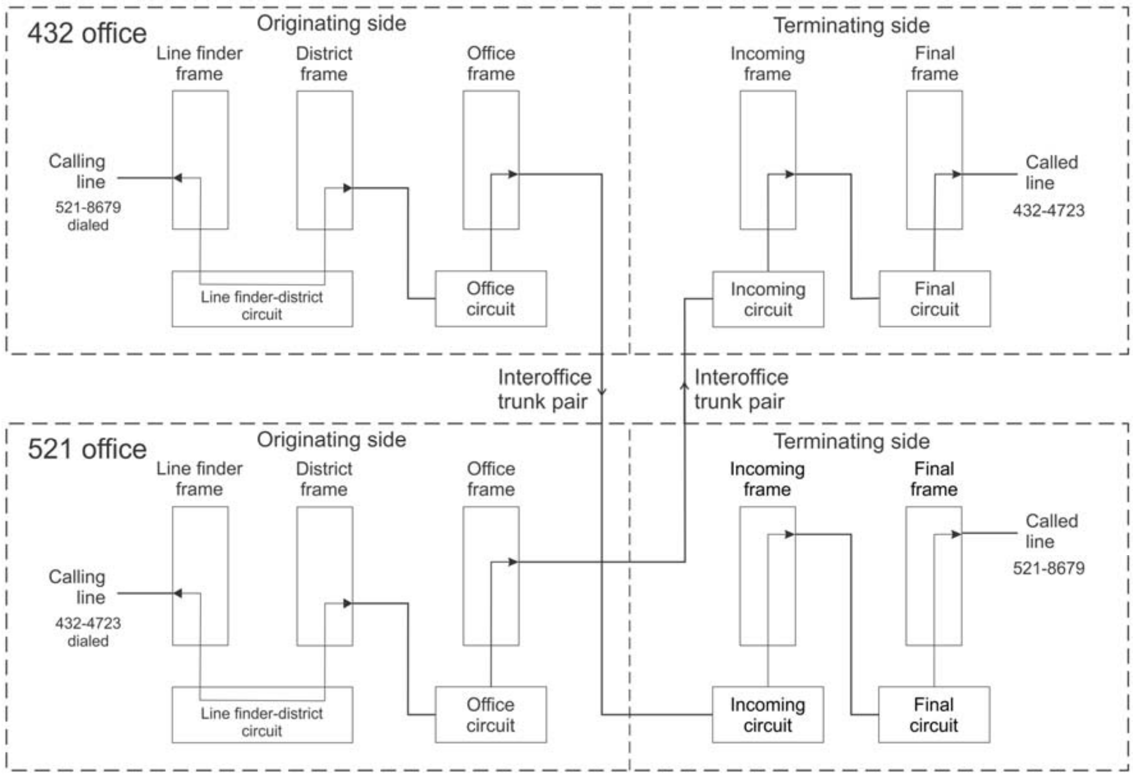

Figure 12. Interoffice calls both ways

In a variant on the theme, seen in figure 13, the outgoing interoffice trunks to one or more distant central offices may come directly from the district frame.

The decision to do this is affected by the amount of traffic expected to the distant office.

The sender is prepared to play this way because the decoder, for a call to a central office to be handled that way, returns to the sender an indication of "skip office", meaning that the office selector phase of the revertive pulsing scenario is just omitted.

For completeness, let me mention that in some cases, a panel office may itself have no office frames. This may be the case in modest sized cities where there are only a few central offices. In that case, all intraoffice calls are handled just as described above for "from the district" interoffice calls.

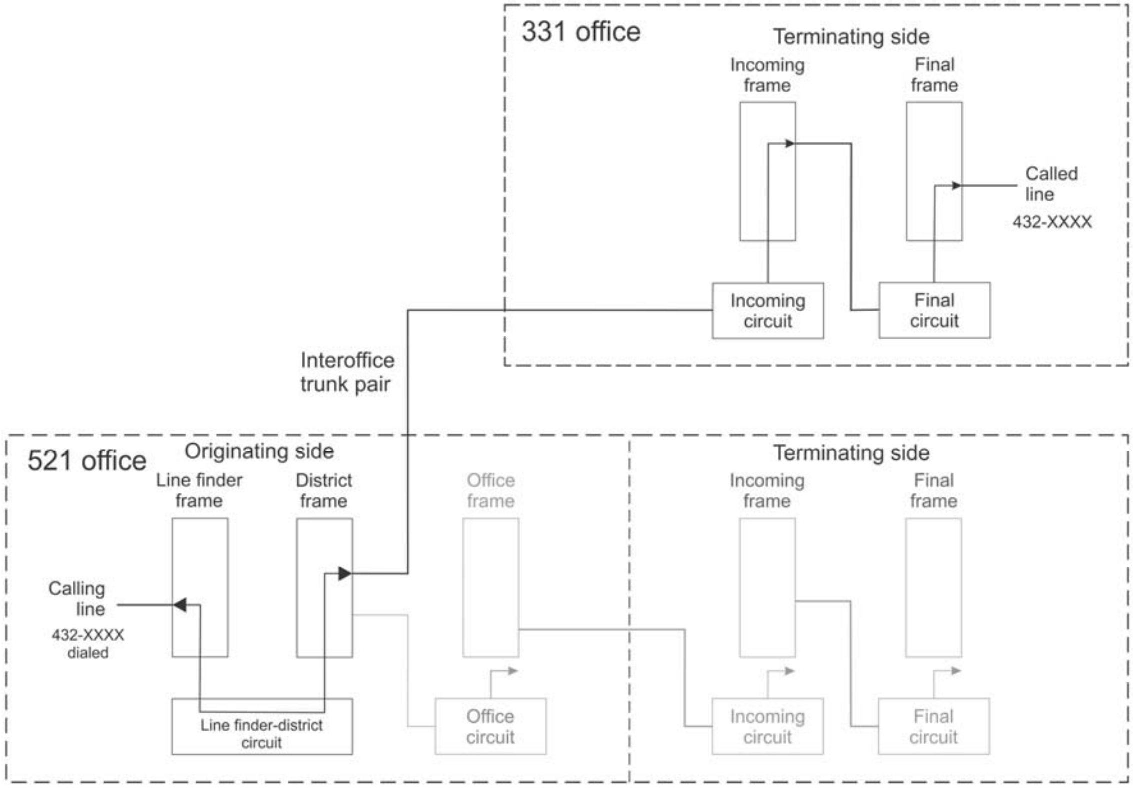

Figure 13. Interoffice trunks from the district frame

4 PCI SIGNALING

4.1 Introduction

When the mechanization of a metropolitan area's telephone service, through the progressive replacement of manual switching central offices by panel dial offices, commenced, various systems had to be put into place so that subscribers now served by panel offices could place calls to subscribers still served by manual offices, and so subscribers still served by manual offices could place calls to subscribers now served by panel offices. The need for these arrangements could extend for ten years or more.

The most desirable systems provided consistency for the subscriber. Subscribers still served by a manual office would still place all calls, whether to a manual office or a panel office, in the long-familiar way: by giving the wanted number to the operator who "answered" when the subscriber lifted the receiver or handset.

Subscribers now served by a panel office would still place all calls, whether to a panel office or a manual office, in the "new" way: by dialing the wanted number after receiving dial tone upon lifting the receiver or handset.

The most important system for allowing subscribers served by panel offices to reach subscribers served by a manual office used a new signaling system developed for the purpose. As it turns out, this signaling system was later adopted for working between a panel office and one of the two types of tandem offices developed for use in a panel switching context.

Accordingly, I will describe it here in some detail. I will begin with a discussion of the original context of its use.

4.2 The original context

The system for handling calls from a panel office to a subscriber in a manual office that is of interest to us was eventually (after its full maturation) called the *panel call indicator* (PCI) system.

The principle is that for such a call, the sender in the panel office sends over the trunk to the manual office the station number of the wanted line. The trunks used for this operation end up in "terminating" ("B") switchboard positions at the destination manual office that have been retrofit with equipment for receiving this number and displaying it on a display panel in front of the operator.

She then completed the call by plugging the trunk cord into the jack for the called line, just as she would have done for a call from another manual office after the "originating" ("A") operator had announced the wanted station number over the trunk.

4.3 The PCI pulsing signaling system

The PCI pulsing signaling system was developed to provide for the transmission of the station number (the part of the telephone number after the central office code) of the wanted station over a trunk to the a "B" position at the destination office, where it was displayed on a numerical panel (the "call indicator") in front of the operator.

The system operated by sending, for each digit, a sequence of four distinct electrical current conditions over the trunk. Those conditions were drawn from this repertoire:

- No current (called "open" from the electrical situation that produced it).
- Light positive current
- Light negative current
- Heavy negative current

The code was actually binary (although the "weights" of the bits were not those most commonly encountered in a binary code). Thus, for each pulse, we needed to have one of two distinct electrical conditions.

In the actual digit format, for the 1st and 3rd pulses (the 1st and 3rd bits), the two possible conditions were *open* and *light positive*. For the 2nd and 4th pulses (the 2nd and 4 bits), the two possible conditions were *light negative* and *heavy negative*.

Thus the receiver, without recourse to any "clock", could follow the progress of the pulses that defined the digits. Accordingly the receiver could be a straightforward relay-based device. Special relays that were polarity-sensitive (so they could distinguish positive from negative currents), and relays that had a closely-controlled operating current (so they could distinguish light from heavy current), were used, but such had existed for many years in telephone switching equipment.

In the context or interworking with manual, offices, the number dialed by the panel office subscriber might have the usual four digits in the "line number" part of the number, but in two cases it would have five.

One case was when the manual office was arranged for up to 10,500 numbers, and so some subscribers had numbers such as "10268". Another case was where subscribers on four party lines would have a "party letter" sufficed to the line number, such as 2873J. To accommodate these cases, there were 5 digits, not 4, included in the entire PCI "message". This worked in rather a mysterious way, which I will not describe here.

We note that to implement this, every sender in every panel office has to be equipped to generate the PCI "message" when called upon to do. Of course, after this was introduced, all new panel offices were normally manufactured with senders that could do so.

We will pick up the significance of the PCI pulsing system on tandem switching in a panel context a bit later.

5 TANDEM SWITCHING IN A PANEL OFFICE CONTEXT

5.1 Tandem switching with manual offices

In section 2.5 *et seq* we learned of the economic motivation to employ tandem switching in a metropolitan area telephone network. And in fact, prior to the mechanization of large city networks via the panel dial system, tandem switching (done of course with manual switchboards of a special type) was employed.

When this was in effect, if the number passed to the "A" operator was served by a distant office, and that office was to be reached via the tandem office, the "A" operator extended the connection over a trunk to the tandem office.

When it was "picked up" by the operator there, an "order tone" consisting of three rapid beeps was sent back to the originating office.

The “A” operator there heard this and spoke the name of the desired destination office. The tandem operator then extended the call over a trunk to the destination office, where it appeared at a “B” position.

When it was “picked up” by “B” operator, an “order tone” consisting of two rapid beeps was sent back to the originating office. The “A” operator heard this and spoke the station number. (There was no need to include the central office name; the call was already at that office.) The “B” operator then completed the call to the wanted station in the normal fashion.

5.2 Tandem operation in operation from a panel office to a manual, office

We heard in section of the way in which calls dialed by a subscriber in a panel office for a subscriber served by a manual office were handled by the panel call indictor system. Here, PCI pulsing was used to send the line number of the wanted subscriber (4, sometimes 5, digits) to the manual office, where it was displayed on a display panel (!) in front of the operator at whose position the trunk appeared.

This overall scheme could also be used where the preferred routing to the destination office was by way of a (manual) tandem office. In this case, the PCI “message” sent by the panel office was expended to include at its beginning the 2 or 3 digits of the central office code of the destination office.

At the tandem office, the entire telephone number was displayed on a display panel (rather larger than those used at destination offices). Based on the displayed central office code, the tandem operator extended the call to the destination office,

When the operator there came on the trunk, the tandem operator received order tone and then spoke the desired line number (only) to the operator at the destination office. The call was then completed in the usually way.

5.3 Panel selector tandem

The benefits of tandem operation for calls between panel offices were initially embraced in a panel network in an amazingly “simple” way. We see it in figure 14.

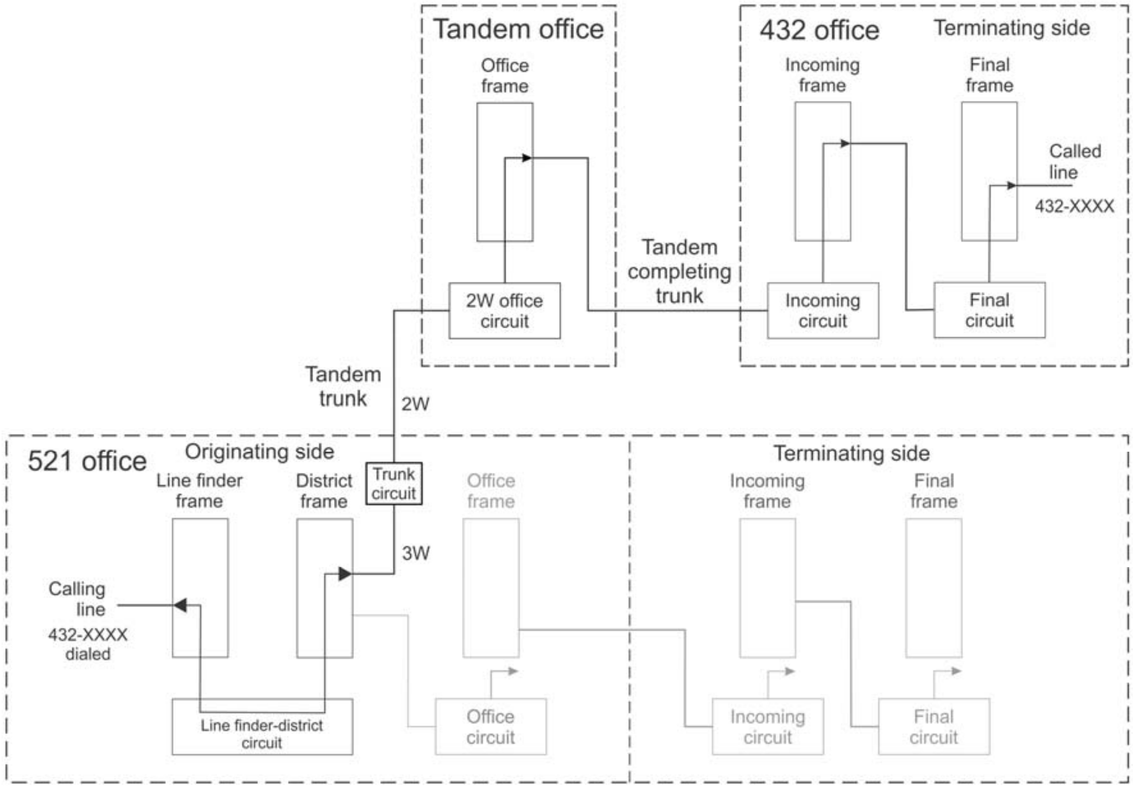

Figure 14. Panel selector tandem

In effect, for tandem calls, the office frame of the originating office is moved into the tandem office. The overall process of setting all the selectors in the train, based on parameters returned by the decoder, proceeds in exactly the conventional way. All the switches in the connection are sent by revertive pulsing, in dialog with the sender at the originating office.

There is one difference. In a normal call through the panel office, the “link” from a terminal on the district frame to the office selector has three conductors, the *tip* and *ring* conductors that carry the fundamental circuit itself plus the *sleeve* conductor, used for various control purposes. [2]

But the trunk that, in this tandem arrangement, leads from a terminal on the district frame to a selector on the office frame in the tandem office has only two conductors.

The panel system relies on electrical signals over the sleeve conductor between the district and office frames to allow the district and office selectors to coordinate as to the status of the setup of the connection.

---

[2] These three conductor names came from the three contact parts of a plug in the manual switching system, but have been carried forward into general use in telephone systems.

In this panel tandem arrangement, this information is conveyed by DC current signals over the trunk tip and ring conductors. At the originating office, a relay unit called a *trunk circuit* mediates between the two situations. At the tandem office, the office selector circuit is set up to work with the "2-wire" signaling scheme (we memorialize that by labeling it a "2W district circuit").

But this scheme, elegant in its simplicity, has limitations. Most importantly, a panel office frame can access at the most 500 trunks, and these can be in not over 50 groups (fewer than that if any of the groups have over 10 trunks).

Thus, in a network of perhaps 200 central offices (easily the case in New York, the "poster boy" for the mechanization of large metropolitan areas), this type of tandem switching is just not suitable.

We note that with "direct trunking", the panel system does not have this limitation. The district frame (this is why we have it) can select among many office frames, each of which can access many trunks in many groups.

We could do something similar with the panel selector tandem only by having each local office access different office selectors in the tandem office over separate groups of tandem trunks., But this would gravely dilute the basic advantage of tandem switching: the consolidation of traffic from one local office to many destination offices.

This type of tandem switching is called "office selector tandem". It is sometimes called "distant office tandem", since its essence is that the office frame is now "at a distance".[3]

5.4 Panel sender tandem

To alleviate the limitations discussed just above with the office selector tandem scheme, a much more sophisticated panel-based tandem switching system was developed, known as the *panel sender tandem* system. We see it in figure 15.

Here, the tandem machine "has a mind of its own", in that it operates with its own senders and decoders. The sender will receive, over the tandem trunk, from the originating office, the complete telephone number (office code plus station number). The operation of the sender,

---

[3] Sometimes we hear it called "distant office multiple tandem". *Multiple* alludes to the fact that on a panel frame, the "output" terminals can be accessed by any of multiple selectors, and thus the whole array of terminals is often called a *selector multiple*. Thus, by a bit of a stretch, the distant office frame becomes a "distant office multiple."

sender link, decoder connector, and decoder are much as we saw them in the basic panel system.

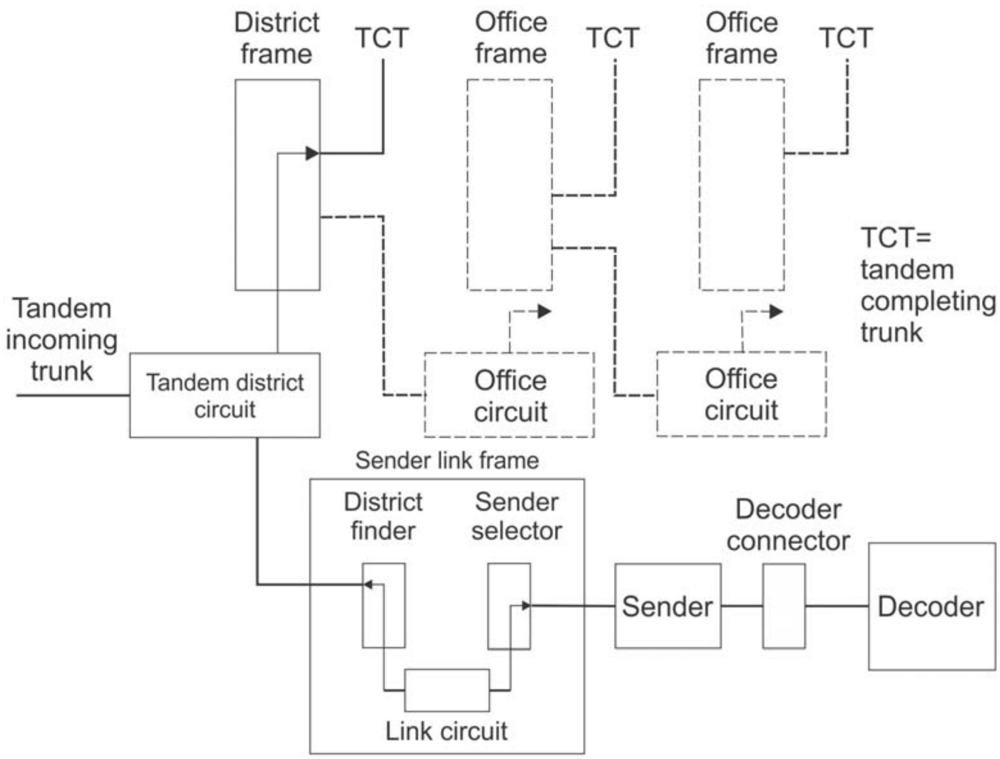

Figure 15. Panel sender tandem

The sender will feed the office code to a decoder, which will return the needed parameters for the sender to set the selectors in the tandem office to reach a tandem completing trunk to the proper destination office. The sender will then play the part of the sender in the originating office and (over the tandem completing trunk, via revertive pulsing) set the incoming and final selectors in the destination office to the terminal for the called line.

Not surprisingly, when this system was being developed, the first thought was that the station number would be sent from the originating office to the tandem office via some form of revertive pulsing.

But it was realized that the PCI pulsing system, already in use for calls from a panel office to a manual office equipped with call indicators, would be much more efficient, faster and easier to implement at the receiving end.

Of course, for use in the panel tandem switching concept, the PCI "message" needed to carry the central office code of the destination station as well as the line number. But there was already the provision for that, needed for operation from a panel office to a manual office via a manual tandem office.

The same digit coding as was used for most of the station number digits was used for the office code digits (two or three, depending on the numbering system in use), with those digits sent before the five digits of the station number, a total of 8 digits altogether. The mysterious fifth station number digit had no role in this *modus operandi* but was included for consistency of format.

Note that I show in the figure three switching stages, an office frame and two successive office frames. Any given panel sender tandem office might have only the district frame stage, or the district frame stage and one office frame stage, or (as shown) a district frame stage and two office frame stages.

And, just as in the basic panel office, even when there is an office frame stage (or two), the tandem completing trunks leaving the office may be accessed on the district frame, or a (first) office frame, or a second office frame. The layout is of course determined by the number of destination offices to be reached and the number of tandem completing trunks needed (based on traffic engineering considerations).

The overall scheme of setting the selectors inside the tandem office via revertive pulsing is conceptually identical to that in a local panel office, except that for a system with two stages of office selectors, the decoder must return up to three sets of selector setting parameters.

Sadly, the great cost of a panel tandem, system was often not justified by te savings it could yield through more effective use of trunks. As a result, only a handful of panel tandem offices were ever put into use, all in very large cities (I believe that New York had two of them).

6 Calls via a panel tandem office to a manual office

While giving the background of the PCI pulsing signaling system, I spoke about the way a panel office can complete a call to a manual office, using the PCI signaling system to deliver the station number to the call indictor display panel at a destination office “B” position.

The panel sender tandem system can participate in this scenario, thus affording the economic advantages of consolidation of traffic in this scenario as well as with regard to calls between panel offices.

The operation from the originating office is essentially identical to what I described just above. But if the destination office is a manual office, the tandem decoder so advises the tandem sender, which then prepares, after it sets the selectors in the tandem office, to send the station number via PCI pulsing to the manual office.

We recall that the “payload” of the PCI “message” included the familiar four digits of the station number plus a mysterious fifth digit, needed to deal with some special situations in the manual office. In all calls via the tandem office, that digit is “recorded” by the tandem office sender. However, in a tandem call to another panel office (where the line number always has 4 digits), it is meaningless (and in fact carries the value “0”; we can think of it then as just a “meaningless leading zero” prepended to the station number).

But if the call is actually delivered to a manual office, and thus the station number is sent by the tandem sender via PCI pulsing, that digit is included in the PCI “message” and at the manual office will serve its usual mysterious purposes.

7 ISSUE RECORD

Issue 1 (this issue), June 15, 2018. Initial issue.

8 ACKNOWLEDGEMENTS

Special thanks go to R.E. Hersey of Bell Telephone Laboratories, whose monumental tutorial on the Panel Dial System (done in 1928-1929 as the “course notes” for an “out of hours” training course) was an important reference for me as I prepared this article.

And thanks to “neverether” for uploading these scans and many other valuable documents from the collection of the Connections Museum, Seattle, to the Internet Archive.

-#-