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2022-01-01 secret military telephone buttons

It's the first of the new year, which means we ought to do something momentous to mark the occasion, like a short piece about telephones. Why so much on telephones lately? I think I'm just a little burned out on software at the moment and I need a vacation before I'm excited to write about failed Microsoft ventures again, but the time will surely come. Actually I just thought of a good one I haven't mentioned before, so maybe that'll be next time.

Anyway, let's talk a little bit about phones, but not quite about long distance carriers this time. Something you may or may not have noticed about the carriers we've discussed, perhaps depending on how interesting you find data communications, is that we have covered only the physical layer. So far, there has been no consideration of how switches communicated in order to set up and tear down connections across multiple switches (i.e. long distance calls). Don't worry, we will definitely get to this topic eventually and there's plenty to be said about it. For the moment, though, I want to take a look at just one little corner of the topic, and that's multifrequency tone systems.

Most of us are at least peripherally familiar with the term "dual-tone multifrequency" or "DTMF." AT&T intended to promote Touch-Tone as the consumer friendly name for this technology, but for various reasons (mainly AT&T's trademark) most independent manufacturers and service providers have stuck to the term DTMF. DTMF is the most easily recognizable *signaling* method in the telephone system: it is used to communicate digital data over phone lines, but generally only for "meta" purposes such as connection setup (i.e. dialed digits). An interesting thing about DTMF that makes it rather recognizable is that it is *in-band,* meaning that the signals are sent over the same audio link as the phone call itself... and if your telephone does not mute during DTMF (some do but most do not), you can just hear those tones.

Or, really, I should say: if your phone just makes the beep boop noises for fun pretend purposes, like cellphones, which often emit DTMF tones during dialing even though the cellular network uses entirely on-hook dialing and DTMF is not actually used as part of call setup. But that's a topic for another day.

DTMF is not the first multi-frequency signaling scheme. It is directly based on an earlier system called, confusingly, multifrequency or MF. While DTMF and MF have very similar names, they are not compatible, and were designed for separate purposes.

MF signaling was designed for call setup between switches, mostly for long-distance calling. Whenever a call requires a tandem switch, so say you call another city, your telephone switch needs to connect you to a trunk on a tandem switch but also inform the tandem switch of where you intend to call. Historically this was achieved by operators just talking to each other over the trunk before connecting it to your local loop, but in the era of direct dialing an automated method was needed. Several different techniques were developed, but MF was the most common for long-distance calling in the early direct dial era.

An interesting thing about MF, though, is that it was put into place in a time period in which some cities had direct long distance dialing but others did not. As a result, someone might be talking to an operator in order to set up a call to a city with direct dial. This problem actually wasn't a new one, the very earliest direct dialing implementations routinely ran into this issue, and so it became common for operators switchboards to include a telephone dial mounted at each operator position. The telephone dial allowed the operator to dial for a customer, and was especially important when connecting someone into a direct dial service area.

MF took the same approach, and so one could say that there were two distinct modes for MF: in machine-to-machine operation, a telephone switch automatically sent a series of MF tones after opening a trunk, mainly to forward the dialed number to the next switch in the series. At the same time, many operators had MF keypads at their positions that allowed them to "dial" to a remote switch by hand. The circuitry that implemented these keypads turned more or less directly into the DTMF keypads we see on phones today.

Like DTMF, MF worked by sending a pair of two frequencies [1]. The frequencies were selected from the pool of 700, 900, 1100, 1300, 1500, and 1700Hz. That's six frequencies, and it is required that two frequencies always be used, so the number of possible symbol is 6c2 or 15. Of course we have the ten digits, 0-9, but what about the other five? The additional five possibilities were used for control symbols. For reasons that are obscure to me, the names selected for the control symbols were Key Pulse or KP and Start or ST. Confusingly, KP and ST each had multiple versions and were labeled differently by different equipment. The closest thing to a universal rule would be to say that MF could express the symbols 0-9, KP1-KP2, and ST1-ST3.

Part of the reason that the labeling of the symbols was inconsistent is that their usage was somewhat inconsistent from switch to switch. Generally speaking, an operator would connect to a trunk and then press KP1, the number to be called, and then ST1. KP1 indicated to the far-side switch that it should set up for an incoming connection (e.g. by assigning a sending unit or other actions depending on the type of switch), while ST1 indicated that dialing was complete. Most of the time telephone switches used other means (digit-matching based on "dial plans") to determine when dialing was complete, but since tandem switches handled international calls MF was designed to gracefully handle arbitrary length phone numbers (due to both variance between countries and the bizarre choice of some countries to use variable-length phone numbers).

The additional KP and ST symbols had different applications but were most often used to send "additional information" to the far side switch, in which case the use of one of the control symbols differentiated the extra digits (e.g. an account number) from the phone number.

MF keypads were conventionally three columns, two columns of digits (vertically arranged) and one of control symbols on the right.

This is a good time to interject a quick note: the history of MF signaling turns out to be surprisingly obscure. I had been generally aware of it for years, I'm not sure why, but when I went to read the details I was surprised by... how few details there are. Different sources online conflict about basic facts (for example, Wikipedia lists 6 frequencies which is consistent with the keypad I have seen and the set of symbols, but a 1960 BSTJ overview article says there were only five...). So far as I can tell, MF was never formally described in BSTJ or any other technical journal, and I can't find any BSPs describing the components. I suspect that MF was an unusually loose standard for the telephone system, and that the MF implementation on different switches sometimes varied significantly. This is not entirely surprising since the use of MF spanned from manual exchanges to modern digital exchanges (it is said to still be in use in some areas today, although I am not aware of any examples), covering around 80 years of telephone history.

I didn't really intend to go into so much detail on MF here, but it's useful to understand my main topic: DTMF. MF signaling went into use by the late 1940s (date unclear for the reasons I just discussed), and by 1960 was considered a main contender for AT&T's goal of introducing digital signaling not just between switches but also from the subscriber to the switch [2]. A few years later, AT&T introduced Touch-Tone or DTMF dialing. Unsurprisingly, DTMF is really just MF with some problems solved.

MF posed a few challenges for use with subscriber equipment. The biggest was the simple placement of the frequencies. The consistent 200 Hz separation meant that certain tones were subject to harmonics and other intermodulation products from other tones, requiring high signal quality for reliable decoding. That wasn't much of a problem on toll circuits which were already maintained to a high standard, but local loops were routinely expected to work despite very poor quality, and there was a huge variety of different equipment in use on local loops, some of which was very old and easily picked up spurious noise.

Worse, the MF frequencies were placed in a range that was fairly prominent in human speech. This resulted in a high risk that a person talking would be recognized by an MF decoder as a symbol, which could create all kind of headache. This wasn't really a problem for MF because MF keypads were designed to disconnect the subscriber when digits were pressed. DTMF, though, was intended to be simpler to implement and convenient to use while in a call, which made it challenging to figure out how to disconnect or "mute" both parties during DTMF signaling.

To address these issues, a whole new frequency plan was devised for DTMF. The numbers and combinations all seem a bit odd, but were chosen to avoid any kind of potential intermodulation artifacts that would be within the sensitivity range of the decoder. DTMF consisted of *eight* frequencies, which were organized differently, into a four by four grid. A grid layout was used, in which there is one set of "low" frequencies and one set of "high" frequencies and "low" was never mixed with "low" and vice versa, because it allowed much tighter planning of the harmonics that would result from mixing the frequencies.

So, we can describe DTMF this way: there are four rows and four columns. The four rows are assigned 697, 770, 852, and 941 Hz, while the four columns are 1209, 1336, 1477, and 1633 Hz. Each digit consists of one row frequency and one column frequency, and they're laid out the same way as the keypad.

Wait a minute... four rows, four *columns*?

DTMF obviously needed to include the digits 0-9. Some effort was put into selecting the other available symbols, and for various reasons * and # were chosen as complements to the digits (likely owing to their common use in typewritten accounting and other business documents at the time). That makes up 12 symbols, the first three columns. The fourth column, intended mostly for machine-to-machine applications [3], was labeled A, B, C, and D.

Ever since, DTMF has featured the mysterious symbols A-D, and they have seen virtually no use. It is fairly clear to me that they were only included originally because DTMF was based directly on MF and so tried to preserve the larger set of control symbols and in general a similar symbol count. The engineers likely envisioned DTMF taking over as a direct replacement for MF signaling in switch-to-switch signaling, which did happen occasionally but was not widespread as newer signaling methods were starting to dominate by the time DTMF was the norm. Instead, they're essentially vestigial.

One group of people which would be generally aware of the existence of A-D are amateur radio operators, as the DTMF encoders in radios almost always provide a full 4x4 keypad and it is somewhat common for A-D to be used for controlling telephone patches--once the telephone patch is connected, 0-9, *, and # will be relayed directly to the phone network, A-D provide an opportunity for four symbols that are reserved for the patch itself to respond to.

Another group of people to which this would be familiar is those in the military from roughly the '70s to the '90s, during the period of widespread use of AUTOVON. While AUTOVON was mostly the same as the normal telephone network but reserved for military use, it introduced one major feature that the public telephone system lacked: a precedence, or priority system.

Normally dialed AUTOVON calls were placed at "routine" priority, but "priority," "immediate," "flash," and "flash override" were successively higher precedence levels reserved for successively more important levels of military command and control. While it is not exactly true, it is almost true, and certainly very fun to say, that AUTOVON telephones feature a button that only the President of the United States is allowed to press. The Flash Override or FO button was mostly reserved for use by the national command authority in order to invoke a nuclear attack, and as you would imagine would result in AUTOVON switches abruptly terminating any other call as necessary to make trunks available.

AUTOVON needed some way for telephones to indicate to the switch what the priority of the call was, and so it was obvious to relabel the A, B, C, and D DTMF buttons as P, I, F, and FO respectively. AUTOVON phones thus feature a full 4x4 keypad, with the rightmost column typically in red and used to prefix dialed calls with a precedence level. Every once in a while I have thought about buying one of these phones to use with my home PABX but they tend to be remarkably expensive... I think maybe restorers of military equipment are holding up prices.

And that's what I wanted to tell you: the military has four extra telephone buttons that they don't tell us about. Kinda makes you take the X-files a little more seriously, huh?

In all seriousness, though, they both do and don't today. Newer military telephone systems such as DSN and the various secure VoIP systems usually preserve a precedence feature but offer it using less interesting methods. Sometimes it's by prefixing dialing with a numeric code, sometimes via feature line keys, but not by secret DTMF symbols.

[1] This was technically referred to as a "spurt" of MF, a term which I am refusing to use because of my delicate sensibilities.

[2] One could argue that pulse dialing was “digital,” but because it relied on the telephone interrupting the loop current it was not really “in-band” in the modern sense and so could not readily be relayed across trunks. Much of the desire for a digital subscriber signaling system was for automated phone systems, which could never receive pulses since they were “confined” to the local loop. Nonetheless DTMF was also useful for the telephone system itself and enabled much more flexible network architectures, especially related to remote switches and line concentrators, since DTMF dialing could be decoded by equipment “upstream” from wherever the phone line terminated without any extra signaling equipment needed to “forward” the pulses.

[3] This might be a little odd from the modern perspective but by the ’60s machine-to-machine telephony using very simple encodings was becoming very popular... at least in the eyes of the telephone company, although not always the public. AT&T was very supportive of the concept of telephones which read punched cards and emitted the card contents as DTMF. In practice this ended up being mostly used as a whimsical speed-dial, but it was widely advertised for uses like semi-automated delivery of mail orders (keypunch them in the field, say going door to door, and then call an electromechanical order taking system and feed them all through your phone) and did see those types of use for some time.