CONNECTING A CONTINENT: AT&T and the Radio Networks

"Everything that once was wireless is now wired. Everything that once was wired is now wireless." *- Rodney E. Nilk*

AN ELECTRONIC "FLYLEAF"

About three years ago, inspired by a piece by James O'Neal in Radio World newsmagazine I came to realize that, while many of us grew up in a broadcast industry created in part by AT&T, there's no easily-accessible access to the full detail of AT&T's contributions. Furthermore, those with first-hand experience in an earlier analog world were retiring and the heritage of experience with AT&T methodology was being lost. This is unfortunate, since AT&T's pioneering formed the practical electrical world in which we operate today.

I also believe there's a body of curious folks of *all* ages who wish to know more about these bedrock principles and about a company that was such a force in early commercial broadcasting.

This work is the first step in satisfying that curiosity. We'll drill down into early telecommunications history (before there was an AT&T) and we'll learn how "The Telephone Company" was born, matured and made its mark in radio and in radio-network transmission.

In its first half-century of service, the American Telephone and Telegraph Company developed and advanced audio connectivity by wire to every home and business in the country…and then used that wiring to expand the reach of radio networks that rode the copper to national coverage.

These communications achievements helped lead to the homogenization of America, when regional boundaries fell and the nation began to experience common community. That happened because citizens could now talk to one another beyond the back fence.

This ‘book’ is a multi-media presentation of honest business effort and anti-competitive practice, vision and pragmatism, technical innovation and practical reality.

In **Chapter One** we follow communications from the “state of the art” in 3000 BC to the patent pool that would become RCA in 1919. We review the technical and business developments that moved us to the world of ‘speech-over-wire.’ “Wired Radio” pre-dated broadcasting by almost a half-century; we’ll look at early efforts and learn how the telephone became the nexus for early telemarketing and political messaging. And we’ll learn how “AT&T” was founded out of the explosive expansion of the telephone industry; its primary goal to *connect the continent*.

Chapter Two takes us into deep technical detail and borrows heavily from telephone company information. This section takes you into the wire offices and development dens where the electrical aspects of long-distance transmission were conceived and implemented. We learn how AT&T Long Lines ‘perfected’ wire performance while searching for an amplifying system that would make transcontinental telephony a practical service.

In **Chapter Three** the story turns to “Wireless” and to how AT&T developed a wired/wireless interface that led to radiotelephony and Broadcasting. We’ll also review the milestones and achievements that led to a mass-media architecture still performing today. We’ll also get a glimpse into AT&T’s culture as they approached the new medium of “Radio.”

Chapter Four tells the story of AT&T’s broadcasting “experiment.” We outline the many “firsts” in long-distance program transmission that in retrospect seem baby steps but which were highly acclaimed as ‘giant leaps’ forward. Chapter Four ends with the story of AT&T’s move out of live broadcasting and back into its core long-distance business.

In **Chapter Five** we track the evolution of the “national” broadcasting networks. We’ll spend some time on the Pacific Coast and we’ll learn of the emergence of new upstart networks and the regional nets that took advantage of inherent deficiencies in the distribution of the big chains.

Chapter Six discusses alternatives to AT&T. Long Lines transmission was expensive and broadcasters sought other ways to get programming from station to station. We see how Short-Wave was used for simulcasting and pressed into service for vital inter-continental audio links.

Chapter Seven concludes our initial review with a deeper look at how AT&T and the radio networks handled multi-channel traffic on the national system. We look at technical performance, learn how AT&T developed operating measurements and standards; observe the evolution of the VU meter and rubberneck as AT&T developed true “high-fidelity” audio transmission through the use of “Carrier.”

There will be a Chapter Eight…and Nine…and Ten…as we develop this series with *your* input. Your feedback will be vital to the ongoing project, and it's the reason why we've published through direct e-mail contact so we can share your comments with all other readers.

Wiring the Country: The overview

AT&T historians will tell you that the company went through distinct development phases after its business-oriented reformation in the early 1900's. That first decade was where it all began to come together. At first, research was centered in Boston to support the experimenters in the field. Meanwhile the phone company was working to establish a monopoly status as a way to ensure their deployment risks would be minimized. Then came the winds of corporate raiding and realignment and a re-commitment to core operating principles. The Regional Bell Operating Companies ("RBOCs") were established and 'end-to-end service' became the watchword.

The third phase in AT&T's development was the building out of national connectivity. Through it all, there was the unbending commitment to ongoing system improvements.

AT&T now took a singular approach to technology: First, the research teams theorized, designed and tested improvements in the labs, and only then were they implemented in the field. This was a marked departure from the Edison-centric methodology of "try this; then try that, until we hit on something." At AT&T, formal operating procedures were published, fine-tuned after extensive experience in the wire offices and then memorialized as *Operating Practices*.

The wire-line development period is when AT&T "wrote the book" on electrical practice for audio transmission. That knowledge base and the company's way of doing things are still applicable a century later…and that's another reason this history is relevant.

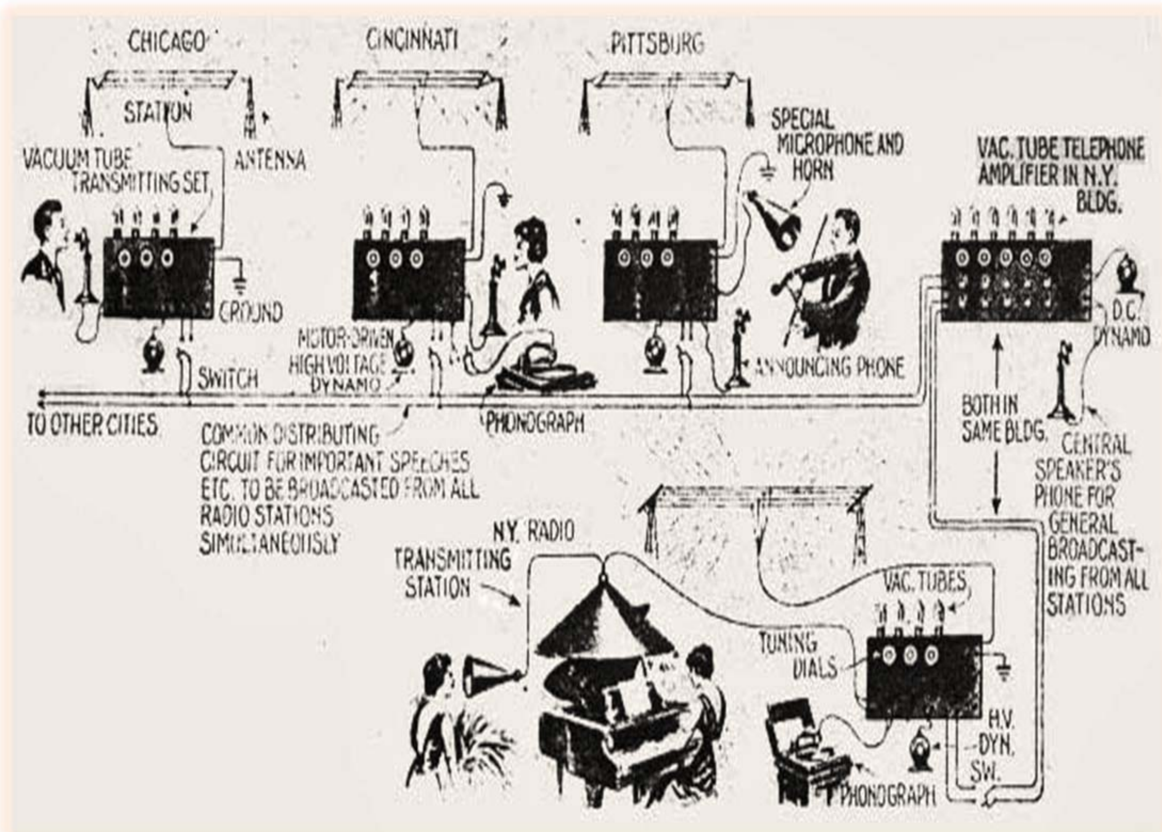
Broadcasting: The overview

The second element of our account involves AT&T and radio. AT&T introduced commercial broadcasting while building the long-distance radio-network backbone. It was obvious from the onset of broadcasting in the United States that radio's political and commercial success would be measured by audience reach. The ideal goal of course was for *each* station to touch *every listener* in the country. But it was clear that, given the physics of the assigned Medium-Wave (or Long-Wave) radio bands, no single radio signal could do this. Multi-station collectivity would be needed. This "station grouping" idea was driven by a clear business fact: costs were reduced when programming expenses could be shared with other stations.

At the time the only practical solution was station-to-station connectivity by wire. And the only wire system capable of doing the job was owned by the telephone company.

At first, AT&T acted like the ‘dog in the manger’ regarding station connectivity via wire-line. Then it became a reluctant partner and finally a full-blown player in building out the radio networks for hire (this ‘networking’ came to be seen as an element of its core business). It was not a simple task; AT&T had to “invent” and “re-invent” along the way.

The early attempts were ground-breaking…yet seem almost naive when viewed through today’s fiber-optic periscope.



Throughout this living work you’ll find references, illustrations and hot-links. Citations will follow each quotation rather than lurking in the rear of the document. Mistakes in the non-quoted copy are purely mine and your comments, corrections and updates are welcome.

We hope it makes interesting reading!

CHAPTER ONE

"Well-informed people know it is impossible to transmit the voice over wires. Even if it were (possible), it would be of no practical value." – *The Boston Post 1865*

The Backstory

"Wide-area networks" go back a long way: 3,000 years for homing pigeons; 800 years for Genghis Khan's version of the Pony Express. 2000 years ago, "long-distance" communications meant signal fires; then carrier pigeons and, in the Olympic Period, marathon runners. Visual (semaphore) relays were found along coast lines a thousand years ago. Simple messages took a few hours to travel from country to country; additional weeks and months *within* those countries.

In the 1700's there was established across Europe and parts of America a crude semaphore network based on basic signaling protocols. "Code books" were used; not for security but so that entire sentences could be transmitted by a few code words. The estimated speed of these links was about fifteen characters per minute.

Messengers and sight-line signaling gave way to electrical communications in the mid-1800's. First was an invention that required third-party intervention (the telegraph); then we advanced to telephone technology that permitted human-to-human conversation without intervention. Very gradually a new vision arose: If we could talk 'one-to-one,' how about enabling a single communicator to reach a mass audience? This could only be done with a "network" of outlets.

Sociologists view a network "in terms of the integration of people, of culture, of the world. Well before radio networks, discourses of progress, integration and modernity were linked to telegraph, telephone, railroad and electricity networks. Radio networks extended this logic of interconnection leading to modern progress and those who were judged to be outside of the radio nation were considered primitive and lacking." *Points on the Dial, Alexander Russo*

Telegraphy: A "Disruptive Technology"

Around 1832 Samuel Morse came up with an electromechanical signaling device he named the "Recording Tele-graph." (He was working with a man named Theodore Vail who later became President of AT&T). In 1838 Morse developed a "standard code" for the on-again/off-again nature of his signaling. The "Morse Code" was in essence the first digital algorithm.

After some years of testing, Morse received a grant from Congress to install a telegraph wire between Washington and Baltimore. On May 24, 1844, Morse sent a message from Washington to Vail in Baltimore: "What hath God wrought!"

The first commercial telegraph circuit was laid between Washington and New York in 1846. Long-distance communication by wire was born. The DC transmission technology was single-wire/ground return. That meant a high voltage (as much as two hundred volts) was needed to overcome ground loss.

The First 'Telecom' Players

Three scrappy companies played roles in early telecommunications development. They were the Bell Company, Western Union (nee "The New York and Mississippi Valley Printing Company") and Western Electric. These companies would integrate, separate, battle each other, marry, divorce…each playing an important role in developing the new technologies.

A few years after the telegraph went into operation a group of entrepreneurs pooled resources to form the Western Union Telegraph Company. The components of the company included 'Outside Plant' (wire-laying), 'Research and Development' and 'Sales/Marketing.'

"Telegraphy became big business as it replaced messengers, the Pony Express, clipper ships and every other slow-paced means of communicating. The fact that service was limited to Western Union offices…seemed hardly a problem. After all, communicating over long distances instantly was otherwise impossible. Yet as the telegraph was perfected, man's thoughts turned to *speech over a wire*." *Tom Farley's Telephone History series* (italics added)

The first baby step in transmitting that '*speech over a wire*' was taken in 1876, when Alexander Graham Bell announced the "speaking telephone." And now we're getting ahead of our story.

Western Union

By the mid-1800's the scramble was on to cross the continent with telegraph wires. Congress passed the Pacific Telegraph Act in 1860; President Lincoln wanted to establish commercial communications with California to keep it in the Union. Western Union opened the first transcontinental telegraph line in 1861. It was a big deal. The story of the "last pole" became famous and one can find photos on line, memorializing the event.

Railroad rights-of-way were used where possible (construction was infinitely easier along the road-bed, access for line maintenance was simplified…and the railroads availed themselves of the wire for their own communications).

In the decade 1851-1861, the number of telegraph stations in the U.S. skyrocketed from 51 to 2,250. Western Union now faced American Telegraph and United States Telegraph in the fight over who would be the bully in the sandbox.

When Western Union bought out the other two in 1856, it became the largest monopoly in the country. (It wasn't the *only* monopoly however: on the news-gathering side there was the Associated Press with its hundreds of affiliates and its choke-hold on news distribution.)

As to Western Union, it certainly didn't hurt matters that the company had friends in the post-Civil War administration. The government deeded to Western Union some 15,000 miles of circuits that had been built for war operations. By the mid 1870's the Western Union telegraph reached every population center in the country.

Western Electric

The telegraphy business needed a strong player to operate in the design and manufacturing arena. Enter Elisha Gray, an Electrical Engineer and a college Physics professor with an interest in long-distance communications. (Gray in fact had developed his own version of the telephone and narrowly lost out to A.G. Bell in the patent application.) Gray was looking for shop support and came across a fellow named Enos Barton, himself in the employ of Western Union as a new-product evaluator and quality-control specialist. Barton saw the potential of Gray's work, bought out his own partner, and he and Gray married their interests in 1869. Their new company (eventually "Graybar") would manufacture and supply telegraph equipment to Western Union while also developing Gray's inventions. The trio opened their new shop in Chicago.

A third partner in this new company was Anson Stager, a former Union General and Western Union telegraph operator. His ties to Western Union opened the door to investment by the monopoly. With new cash in hand, in 1872 the partners opened their doors as The Western Electric Company, and became the principal supplier to Western Union. Western Electric would play a critical role in design, technology and standards support far into the Twentieth Century.

The Telephone: 'Can You hear me now?'

1876 was a watershed year in communications. The new Western Electric Company scored five gold medals at the Philadelphia Centennial Exposition for its telecommunications products. If you spent a few hours at the Exposition, you marveled at their progress. If you walked across the hall you could see the new invention by Alexander Graham Bell that sent speech over a wire.

The first “Telephone”

Sound archivists have recently discovered a recording of Alexander Graham Bell’s voice. Here’s Bell’s voice, in 1885 http://www.durenberger.com/bell.mp3 *Smithsonian Collection*

Now a great story about how Bell developed his “voice-over-wire.” We invoke a century-old recording of Thomas Edison, himself a good friend of Bell’s. Edison’s reputation as a credit-hog is refreshingly absent: http://www.durenberger.com/edonbell.mp3

“Hello Central”

“Station-to-station” technology developed to the point that instruments talked with each other, and the focus turned to building out the wire paths into an interconnected “network” so that any instrument could be *switched* to any other. The logical approach was to treat all telephone instruments as devices hard-wired into a “star” system. The star system lent itself nicely to a core “server” that was a cross-connecting switch (nee: manual switchboard), central to the telephone serving area. Thus were developed “wire offices”…the hub of the “star”… that terminated all subscriber lines and provided the switching to connect any telephone to any other.

In this early telephone world, the distance from the core of the star to any outlying instrument (hence the wire office serving area) was limited by the efficiency of the device and the loss in the connecting lines. It was typical to expect about a 20 mile useful range; this limitation drove the architecture of local telephony for years to come.

Following the success of the Philadelphia Exposition, A.G. Bell and partners Tom Sanders and Gardiner Hubbard formed the Bell Patent Association and continued to file and perfect their applications. The partners opened "The Bell Telephone Company" in Boston in 1876 and offered licenses to any company willing to play by their rules (and of course pay a license fee). The New England Telephone Company emerged, offering a novel plan under which subscribers *leased* rather than owned their instruments. The first "telephone exchange" was turned up in New Haven Connecticut in 1878.

Once the genie was out of the bottle, the clamor arose for connectivity *between* communities (anything outside the reach of the local wire office was 'long-distance.') There were also standards issues: the requirement that all telephones be able to work with all other phones and with the networks connecting them. At times during the "Wild Wild West" of free-for-all telephony, these seemed insurmountable obstacles. But, as with any disruptive technology, the evolution was too big to be stopped.

The demand detonated; the number of telephones (and wire offices) increased almost exponentially. Hundreds of "telephone companies" went into business…while certain corporate giants viewed the communications explosion as worthy of dominance for profit.

The growth of the New England model and the need for Bell to control his invention resulted in formation of the National Bell Telephone Company in 1879 and, with it, the International Bell Telephone Company. (The latter would fight patent infringements in Europe.)

Western Union Hubris

New England notwithstanding, after Bell secured the telephone patent, his firm found itself with a great idea but without the cash to pull it off. Bell visited Western Union, proposing a sale of his telephone patent for about $100,000.

Western Union meanwhile had been buying patent rights from several independent telephone companies, forming "The American Speaking Telephone Company" in 1878. Armed with a small collection of patent rights and flushed with its own success in telegraphy, Western Union rejected the Bell offer and instead bulled ahead with its own telephony plans, confident in its deep pockets and its national dominance in telegraphy.

Bell immediately filed suit against Western Union for patent infringement. The companies settled out of court in 1879; they agreed henceforth not to compete with each other. Western Union dropped out of the telephone business, agreeing to stick to telegraphy and messaging. Bell handed its telegraph business to Western Union and agreed not to use the telegraph for general, news or business messaging.

Bell then purchased existing Western Union telephone assets and added a cash payment. Most importantly, Western Union recognized Bell's patents. These dealings could only happen at a time when there were no rules for business other than those that benefitted business concentration. In spite of the acrimonious nature of the patent-infringement settlement, Bell and Western Union again married (and divorced) a few years later.

Since "Universal Service" was a core driver in the Bell Company's business model it was critical to set standards and to enforce them. At the same time large-scale manufacturing was needed. There was only one obvious choice for Bell: Western Electric. General Stager and Theodore Vail put the deal together in 1881. Western Electric now became the exclusive provider of telephone equipment to the Bell Company. The tale is enriched by a footnote: while Western Electric was sole provider to Bell, it also provided equipment to the *competition*…until Bell finally bought Western Electric and locked it up.

Meanwhile, Western Union was facing an internal battle of its own. Financier Jay Gould decided to take over Western Union from fellow robber-baron William Vanderbilt. Gould, as a business tactic, announced formation of "The American Union Telegraph Company." It was a paper competitor…meant to dilute the value of Western Union stock. (Privately Gould also sought to refresh Bell's offer to sell, but it was too late.)

As various basic telephone patents were expiring, American Bell moved to secure its hold on the business. The company encouraged continuous development of telephone instruments and so balanced its goal of complete control with the pragmatic recognition that, in the developers' world, independent operators had ideas too.

"Long Lines"

Now Theodore Vail shared a vision: Collate the various Bell companies into a nation-wide telephone network providing "end-to-end" service, with the various Bell nodes in the network serving as the "last-mile" between network and customer. "Long Lines" was born. In a business reorganization, the National Bell Telephone Company became The American Bell Telephone Company in 1885.

A junior division of the new company called **The American Telephone and Telegraph Company** was formed for the purpose of developing "long-distance" communications. The initial Charter: *"Connect one or more points in each and every city, town or place in the State of New York with one or more points in every other city, town or place in said State and in each and every other of the United States, Canada and Mexico; and each and every of said cities, towns and places is to be connected with each and every other city, town or place in said states and countries, and also by cable and other appropriate means with the rest of the known world."* *AT&T Files*

In 1890 American Bell published the prediction that ultimately "*the lines used in the daytime for business affairs will at night carry music, lectures, and various oral entertainments to all the cities…of the East*." *Ibid* (underlining added).

Mention of "the East" reflected a population-centric mindset and recognized the reality of the cost of serving the sparsely-populated West. The concept of 'thin-route' communications was a long-term concern for investors; it underpinned a mandate of regulatory and franchising authority: Any company granted a license for high-density, high-revenue markets would also have to provide (more-expensive) *rural* connectivity.

Wiring the nation for long-distance telephony was an incredibly ambitious project. Baby steps became those of seven-league boots. The first permanent long-distance circuit was turned up between New York and Philadelphia in 1886 and was an instant success. By 1892 the lines were extended to Chicago. In building out these (passive) circuits, developers had to contend with single-wire plant (acceptable for telegraphy but increasingly unsuitable for voice). Bell already knew the practical approach was balanced wire-pairs; installation of paired circuits began in 1890 and total network conversion to balanced circuits took more than 10 years. It was difficult to finance (many subscribers felt even with hum and noise the old system was 'good enough.')

Two years after kick-starting his long-distance plan, Vail left the company, just as various telephone patents were expiring and the predictable telephone wars heated up. But Vail's vision had given American Bell a formidable leg-up in the long-distance business. He would return 25 years later, to guide AT&T through its developmental years.

On the last day of the 19th Century, American Bell folded itself into its subsidiary and became **The American Telephone and Telegraph Company.** Its business purpose was to provide end-to-end long-distance voice connectivity. "Long-distance" was the first goal; the first- and last-mile components would be added in 1911.

Wired "Radio"

While Bell is regrouping and the promotions people are lining up their new image campaigns, we step back for a moment to the 1870's to see what folks were doing with the telephone lines beyond point-to-point telephone calls. It's interesting to observe the vision of "mass communications" now penetrating the thinking of some Futurists.

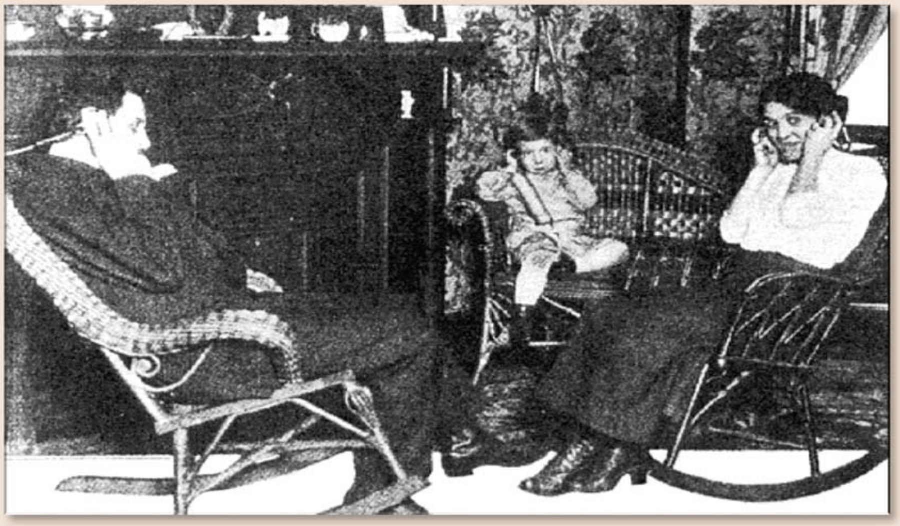
From 1876 comes a report that symphonic music was sent down (idle) telegraph lines for the entertainment of telegraph operators along the line. (We're not sure how the music bridged the telegraph repeaters, so we relegate this one to the 'doubtful anecdotes' folder.)

“At the 1881 Paris International Electrical Exhibition, Clément Ader demonstrated the transmission of music from local theaters using telephone lines. Ader's use of dual lines also introduced the phenomenon of stereo listening -- at the time referred to as ‘Binauriclar Auduition.’" (Say that aloud.) *Thomas H. White* *http://earlyradiohistory.us/index.html*

No one picked up on the stereo concept…“Stereo Realism” was ahead of its time. In later years the BBC presented a program entitled “The Hearing Aid” in which we learn about the Paris experiment: http://www.durenberger.com/parisstereo.mp3

In 1893 Telefono Hirmondo, arguably the most successful telephone-based service in the world, came on the ‘air’ providing news, weather, readings, lectures and other entertainment to some 6,000 telephone subscribers in Budapest. (Reach was limited to a practical distance from the serving wire offices.) Telefono Hirmondo was an ambitious project and extremely popular in the Hungarian capital. It was the most successful of the (pre-wireless) “broadcasting” attempts.

In 1895 a telephone-based “broadcast” system opened in London. Queen Victoria was a listener. It was expensive and it soon disappeared. A Detroit company announced “The Tellevent” in 1907 as a news offering with music and live performances. It may never have launched. Holland reportedly had the largest wired system; some 170,000 subscribers were counted.



Because the marketing area was limited by the need to be close to a telephone exchange, wired entertainment didn't catch on in the United States. The most legitimate of the American launches was that of the New Jersey Herald Telephone Company…meant to be a model for a national system. It gained decent press and some 5,000 subscribers, but lasted only a couple of years. Demos in other areas received enthusiastic reception but not enough funding to launch.

Thomas H. White reported on "the *Tel-musici* of Wilmington, Delaware, a pay-per-play phonograph offering, where…home and commercial subscribers rang a central office to request tunes played back over their phone lines…A short notice in the September 21, 1912 *Electrical Review and Western Electrician*…announced that a recorded music service had been inaugurated by The New York Magnaphone and Music Company…the August, 1913 *Technical World Magazine*, enumerated a range of potential applications, from basic public address for train stations and baseball stadiums, to a multi-channel sound system for movie theaters, and even as a remote speaker for audio sent over telephone lines from a central location for movies viewed at home…the January, 1913 *The World's Work*…emphasized the possibilities of telephone-distributed news and entertainment, declaring that "There is a talking ticker now, a machine that will entertain and instruct you for twelve hours on a stretch with the gist of the day's political speeches, baseball scores, election returns, and any other news that seems important." But this apparently was another case where the technology once again fell short of commercial success" *Thomas H. White* http://earlyradiohistory.us/index.html

A few years later a service expansion contributed to the demise of "wired radio." As radio emerged, a combination offering called a "wireless relay exchange" gave subscribers a way to listen to broadcasts without buying an expensive receiver. The signals were captured by a central receiver at the telephone company, then fed over telephone lines. It was one of those feature additions that was self-defeating when the price of radios dropped to within reach of all.

That wasn't the end of the wired concept. By 1922 there was "store-casting" going on in Washington D.C., Staten Island and Cleveland Ohio. It was music only; no announcements. (The offering in Cleveland was named "Muzak.")

The October 1926 Radio News magazine related the description of entertainment delivered by RF carriers over telephone and power lines. Receivers plugged into electrical light sockets could grab the signal from the electric mains. The system proposed was to be capable of three simultaneous program transmissions via three separate RF carriers. It never caught on. They called this early technology "carrier-current."

In 1932 a new form of wired radio was applied with some success in Britain, Belgium, Switzerland and Holland. It was marketed against radio on the basis of "no interference, no noise." Any radio that plugged into a wall outlet picked up the signal.

Then in 1936 Radio News suggested "wired radio was catching on in restaurants hotels and nightclubs." Program offerings included wired music, ticker news and tele-facsimile. This version of wired radio used specially-conditioned telephone lines. Audio was fed to loudspeakers at the destinations. "Foretell" (flash sports news) was the chief program offering, with music used as fill material. "Ticker News" was described as an 'audible newspaper.'

"A novel part of the wired music services is that the timing of selections is almost identical to that of average metropolitan restaurant entertainment. For example after a few selections there is a period of silence. This program gap simulates the intervals in the dining spots when the players leave the bandstand for a smoke and rest. (Silence) gaps are controlled at the wired music studios; the loudspeaker units being left turned on continuously at subscriber outlets."
Excerpts from Radio News: January 1936

The article goes on to declare that similar setups were established in Boston and Philadelphia, Baltimore and Chicago.

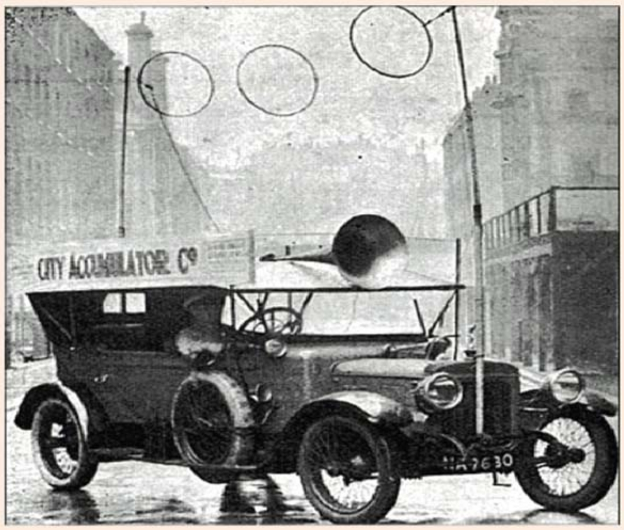
Early Telemarketing

In the early 1900's savvy marketers began to target wired homes for the purpose of "direct marketing." A trade-magazine article reported that a Fairmont, Minnesota store found telephone soliciting much more effective than "sending clerks or errand boys" to inform potential clients about store specials.

An electric power company advised its offices to call potential customers at home, noting that regarding the time of calling…"it is suggested that between 8 and 9 PM is preferable, owing to the fact that the head of the house is generally in at that time and a sufficient length of time has elapsed after the evening meal so he would be in a receptive mood."

The telephone was also employed in the political arena for ‘get out the vote’ calls…and promoters suggested that this approach ought to be adopted by "all up-to-date political managers who want to reach the people in the right way and at the right time.”

Telephone solicitations were credited with influencing the outcome of the General Election of 1912. Recorded political speeches were played down the phone to prospective voters. (Political recordings were also played on truck-mounted loudspeakers cruising the streets; in vaudeville halls, political parlors, churches, schools and shops.)

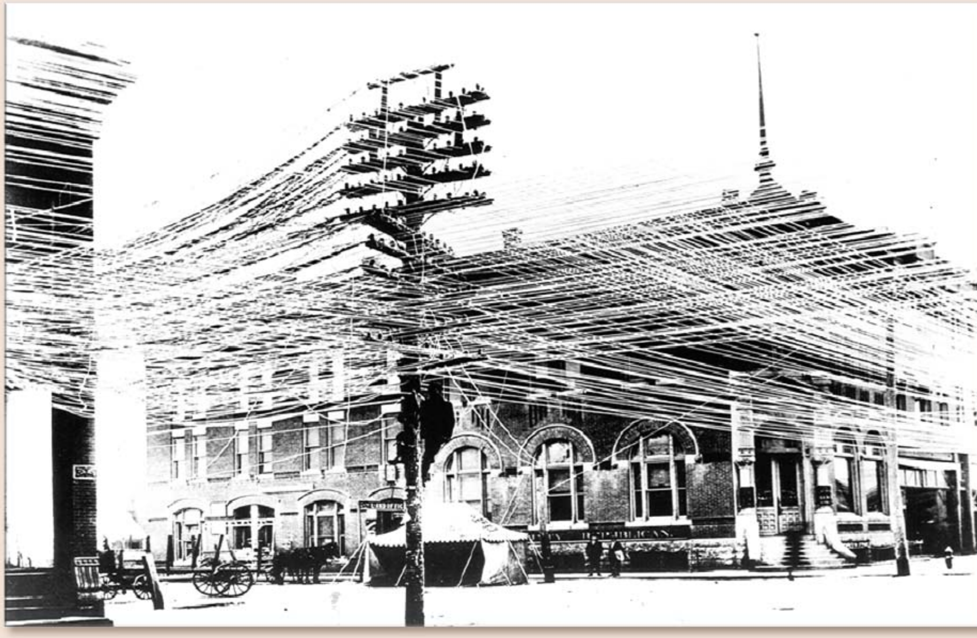


Here’s one such political recording of President McKinley in 1901: http://www.durenberger.com/mckinley.mp3

These efforts assumed constituents were interested in political messages; the truth is likely they were attracted by the *novelty* of the offering. That novelty quickly dissipated.

In the early 1900’s the telephone companies were feeling their way. It had been some time since subscribers had tolerated the hum and noise on single-wire circuits; subscribers were becoming more demanding and wanted farther reach. Priorities turned to evaluation of network design. Most early problems were equipment-related; once they were resolved, poor wire-circuit performance was the next challenge. (Exacerbating the situation was the lack of adherence to standards by some inter-connecting telephone companies.) In the labs, focus turned to reducing electrical interference.

An obvious solution was to bury the lines where possible.



Underground toll cables were first deployed between New York and Philadelphia in 1906 and buried cable used in several cities in an attempt to help clear up the overhead mess.

AT&T's Board Room Struggles

While AT&T engineers were busy in the field with the networks, financial titans were wrestling for control of the new company (a struggle not unlike that at Western Union 25 years earlier). Financier J.P. Morgan had the biggest club; his acumen, resources and connections brought him control of the newly-named company. Management was re-aligned.

The man Morgan wanted to lead the company in a new direction was…Theodore Vail. Vail signed back on at AT&T in 1907. He modified the company's charter; the new watchword was QUALITY. Quality as an operating objective became the benchmark for long-term investment in the Long Lines network and quality would be a benchmark of AT&T's reputation.

In 1908 AT&T announced the slogan: "**One Policy, One System, Universal Service**."

Even after the resolution of the board brouhahas, AT&T kept busy a battery of white-lipped attorneys. It refused to sell connecting equipment to those independent telephone companies who had not signed licensing agreements. AT&T also stipulated that only *licensed* independent telcos could connect with their long-distance network.

This position and a thirst for acquisitions led to government investigation into AT&T's "predatory practices." Looking to expand its control of the industry, the company had tried to acquire the Postal Telegraph Company but couldn't strike a deal.

Western Union, meanwhile, had been hemorrhaging from competition in the telegraph business and was an easier target. A merger between the former enemies was inked in 1909. It could only happen in Big Business.

Alarmed by developments, in 1910 the Federal Government by means of the Mann-Elkins Act vested certain interstate telephone toll-rate authority in the Interstate Commerce Commission. It was a shot across AT&T's bow. Out of this new oversight came a government antitrust suit that led tothe "Kingsbury Commitment" of 1913 wherein AT&T agreed to allow independent telephone companies to connect to its network. (AT&T also had to stop bullying or buying other telephone companies…and in 1914 had to shed its recent interest in Western Union.)

The Kingsbury Commitment freed the phone company to refocus its business.

A Long-distance Telephone Call

The telephone network had practical mileage limits. Bell engineers now used technology to squeeze additional miles from their passive circuitry. But without a way to *amplify* the voice signal, a useful distance limit would soon be reached…and it was far short of national coverage.

Nevertheless, in 1909 AT&T announced *it would have transcontinental telephony working by the opening of the Panama Canal Exposition in 1915*. The challenge to Engineering came from AT&T's Chief Engineer John Carty, himself one of Vail's earliest hires.

Carty had taken the train to San Francisco to consult with Pacific Tel about some engineering problems. He found himself cut off from all but telegraphic communication with his New York offices. At the same time, Carty (and Vail who was also on the Left Coast), were facing pressure from Pacific-based businesses for national voice connectivity. AT&T was also concerned that advancement in European technologies might push them out of total control of the business.

Vail and Carty agreed to put the company's prestige on the line with the 1909 announcement. Engineers had less than five years to deliver.

Long Lines issued a call for technology and lit up its internal development teams. Not to give away the ending of this account, but the coast-to-coast line was in fact ready in 1914, six months before the (delayed) opening of the Exposition. AT&T used the delay to perfect its circuit. How many of us would love to be given an additional half-year past the due date for our projects!

Telecommunications in the Great War

America's entry into World War One tipped a lot of priorities upside down and led to AT&T's interest in wireless.

Wartime experience uncovered the potential for counter-offensive inherent in wireless communication: on the battlefield enemy signals could be intercepted, and direction-finding techniques could locate the positions of enemy transmitters.

In August 1914, the German Army used vital intercepts to defeat the Russian 2nd Army in the Battle of Tannenberg. And it was detection of wireless traffic that alerted the British navy to the movements of the German fleet and precipitated the Battle of Jutland in May 1916.

General John Pershing went to the Mexican border in 1916 in an attempt to capture the Mexican revolutionary Pancho Villa. U.S. Army signal operators went into the field with Pershing, dragging their “mobile sets.” (It took several horse-drawn wagons to haul the gear; one wagon just for the batteries!)

Once the U.S. entered World War One, the U.S. Navy was all over wireless. Huge government contracts awaited businesses that advanced the development of these potentially-decisive tools of war. Naval officials saw the military implications of direction-finding and for communications among ships. (Post-war, the Navy tried to maintain control over wireless but American industry was having none of it.)

Then the Army announced it wanted radio for its aircraft. AT&T and Western Electric jumped onto the runway. “Aircraft-to-Ground” voice transmission was demonstrated in 1917. Shortly thereafter, planes could communicate with each other (via telegraphy!)

In 1916, for security reasons, the U.S. Government ordered all amateurs and experimenters to shut down for the duration; they even had to dismantle their receiving sets (a very few established stations were given limited test authorization). Amateurs and experimenters went into their garages and basements and kept tinkering.

Control over Broadcasting in the United States

The Navy made a grab to extend its wartime control over wireless but American industry fought back. The immediate dilemma was a concern over the potential of British domination of wireless, as represented by the British Marconi Company and its American subsidiary. It all came to a head in a skirmish for control of the Alexanderson High-Frequency Alternator. The British made a play for it; the Americans reacted. The Navy, finally despairing of its desire to control wireless in the U.S., supported a plan involving the creation of a powerful private American "patent pool" to take over the radio patents and resources that would be released to their original owners at the end of World War One.

GE's control of the Alternator made it a major player in the discussions. The other major companies with deep interest in a patent pool were AT&T and Westinghouse. The final piece was American Marconi, and negotiations with British Marconi resulted in the sale of its interests in American Marconi and the inclusion of those interests in the new government-supported patent-pool company. The Radio Corporation of America (RCA) was formed in 1919. (Within less than a decade RCA would be David Sarnoff's private playground.)

In the new company, wired telegraphy and telephony were reserved to 'The Telephone Group' (AT&T), "space" communications remained the dominion of RCA and its partners (known as 'The 'Radio Group'). The Radio Group was given exclusive rights to produce and sell "devices for the reception of news music and entertainment…at the other end of the process, rights in devices and stations for transmitting such programs was left in an ambiguous contractual state…it was destined to provoke one of the great industrial conflicts of that generation… between the telephone and electric interests for primacy in the broadcasting field."
From 'David Sarnoff' by Eugene Lyons

Westinghouse came into the pool with its many radio patents and licenses and in return was given a 40 percent share of the rights to manufacture for RCA. (When Westinghouse joined the Radio Group, RCA took over management of the Westinghouse New York station WJZ but that story remains to be told.) Significantly, AT&T was licensed for "Toll Broadcasting."

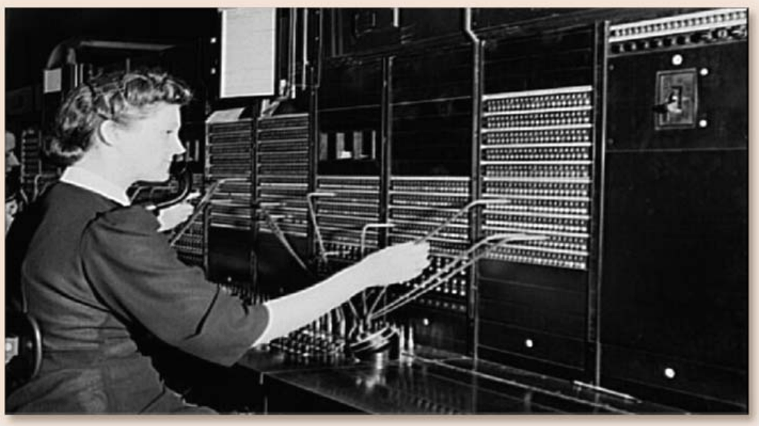
Immediately there emerged a dispute as to who could build and operate the stations for the new "radio broadcasting" business. The Radio Group claimed primacy. AT&T, in reaction to its interpretation of the agreement, sold its stock in RCA and declared war. The agreement wasn't proving to be definitive and its interpretation would be the subject of a protracted battle. *ibid*

End-to-end calling

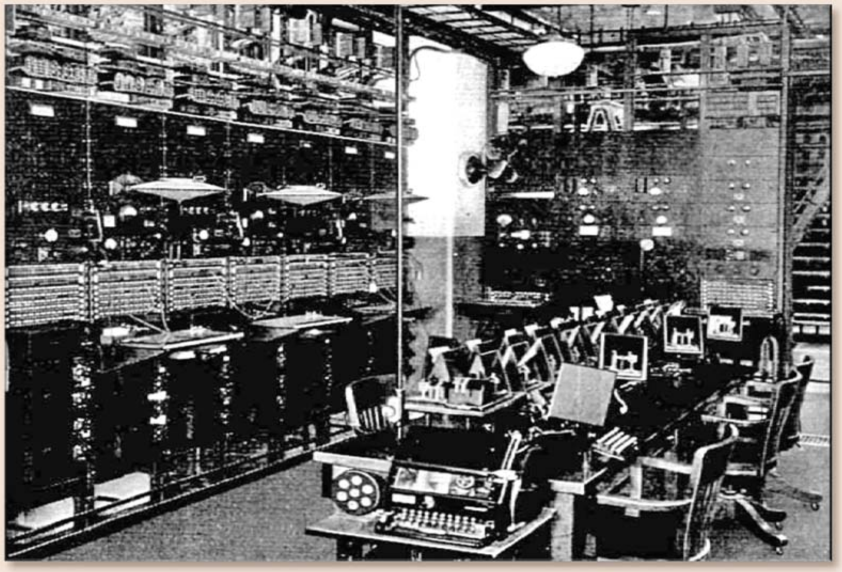
The telephone network was now ubiquitous, but it was cumbersome to place a telephone call. "For many years, all long-distance calls began with connection to an operator sitting at a toll (long-distance) switchboard. Until the 1920's, that operator wrote down the calling information provided by the customer.

The operator then passed the information to another operator, who looked up the route that the call should take, and then built up the circuit one link at a time by connecting to operators at switchboards along the route. A typical long-distance call took seven minutes to set up. Once operators established a circuit, it was dedicated to that conversation until the end of the call." *AT&T History of Network Switching*

We've taken the following clip from a CBS "Suspense" broadcast called "The Hitchhiker." It's a bit over the top, but illustrates what you had to do in placing a long-distance call. http://www.durenberger.com/ldviaoperator.mp3



And that's about enough background. We know who the players were, we know what was driving AT&T and we have some understanding of how the company operated. With Twenty-First Century hindsight it's almost embarrassing to see how they struggled to develop what now seems old-fashioned. But it was a grand experience in its time.



CHAPTER TWO

AT&T Builds a Voice Network: A nice amount of technical detail

As giant corporations go, the history of AT&T is one of the best-documented. The theory and practical expertise developed 100 years ago is in many cases still useful in the 21st Century. They did not throw 'the book' away once written; chapters were simply added.

Prior to 1914, telephony was limited by distance. You could move voice just so far on a pair of wires. The low audio output of telephone instruments fought against noise on the wire path.

Improving Wire Performance by "Balancing"

In the Western Electric labs around 1906, work focused on wire/equipment interfacing. There was just no way the single-wire Western Union system worked for audio. Not only did high ground resistance dramatically increase loss, but the unbalanced single (iron) wire was highly susceptible to electrical field disturbances. One of the more predictable effects resulted from the placement of wires along railroad rights-of-way. Inductive and capacitive reactance was upset as trains rolled by, and noise fields generated by the trains were induced in the wire.

The first significant improvement in balancing had been the two-wire transmission line and conversion to balanced two-wire circuits for telephony began around 1890, as we noted.

The wire pair looked like an AC transmission line whose impedance was a complex vector, consisting of distributed resistance, capacitance and inductance. Good signal-to-noise performance required "balancing" the end terminations to minimize those complex effects.

Engineers directed their efforts toward understanding the problem. (Their work is applicable today so we'll use the current tense occasionally…forgive us if we use the language of the time when referring to "cycles-per-second" rather than "Hertz.")

Two terms came into the lexicon. "**Metallic-Circuit Noise**" is a voltage that appears *between* two conductors in a pair. Metallic Circuit Noise is known today as "differential noise."

"**Longitudinal-Circuit Noise**" is a voltage that *exists equally on both wires* of a pair ("common-mode noise"). These voltages are observed with respect to ground

Longitudinal noise usually results from proximity to interfering sources where both wires are equally susceptible. This interference includes inductive coupling from power lines, parasitic leakages, perhaps capacitance between offending and affected lines. Paired wires, whether open-wire or cabling, require *twisting* the pairs to induce common-mode voltages on both wires, so it can be cancelled at the input transformer.

One early application to minimize these effects on open-wire lines was "Transpositions." Open wires were made to cross each other (each crossing created a 90-degree shift) at distances such that several transpositions occurred per wavelength of audio. This was an elemental form of "twisted-pair" line. (High-voltage transmission lines still use this technique, as do cables.)

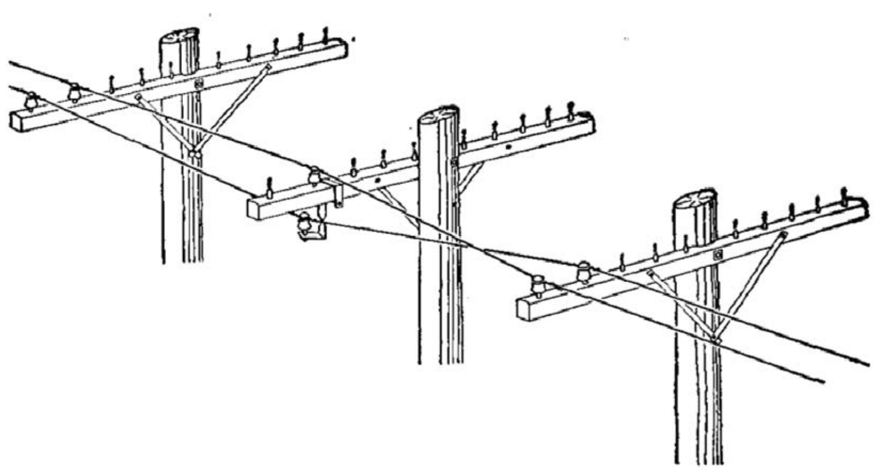


FIG. 34-12. DROP-BRACKET TRANSPOSITION

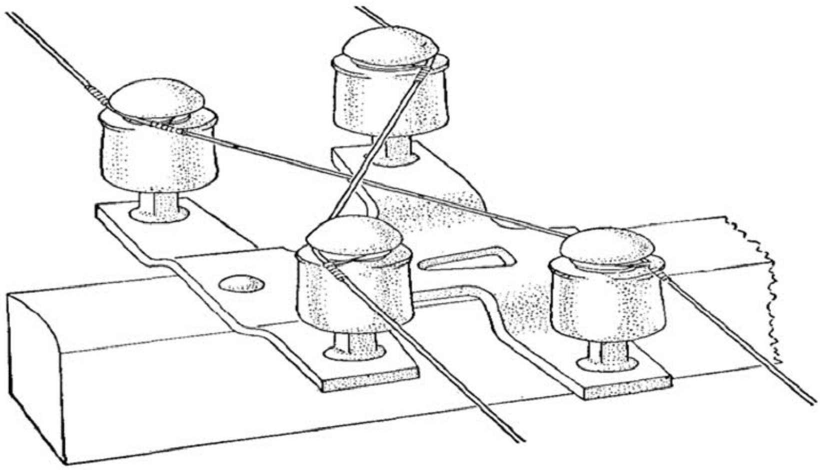


FIG. 34-11. POINT-TYPE TRANSPOSITION

Courtesy Bell Systems Technical Journal

Balanced Terminations

A wire circuit provides best balance when it meets well-balanced, well-matched terminations. A look at transformer design shows how Western Electric approached this. In the transformer, Longitudinal-Circuit Noise transfer is minimized by the design of coils with precisely-matched windings on both halves of the center-tap. Given the nature of this noise, it occurred to engineers that grounding the center-tap on the transformer ought to cancel out this interference. Unfortunately, unless the transformer was perfectly wound, there would always be slight imbalance currents flowing.

A perfectly-wound (and balanced) transformer was tough to make; layered coil construction was easier. But, by the construction, layered coils were not precisely balanced: one winding had slightly more wire.

Longitudinal (common-mode) noise can be reduced by the use of electrostatic shielding. This shielding reduces inter-winding capacitance (leak-thru) between primary and secondary. On the drop (equipment) side of a transformer, the connection was usually unbalanced against ground. Thus, leakage through the transformer became Metallic-Circuit Noise and was transferred to the following stage…usually an amplifier input.

The best transformer designs use electrostatic shielding on both primary and secondary windings. In that case any noise currents flow from one *shield* to the other; both grounded.

Western Electric engineers' ultimate design was what we now call the "Repeat Coil." They did pretty well at it; their early work endures as a benchmark for good transformer design. The repeat coil got its name because its primary function was to transfer energy from one circuit to another without loss or added effects.

The ideal repeat coil minimized imbalances and noise transfer from the "Loop" side to the "Drop" side. More versatile coils also handled impedance-transformation. Beyond providing good balancing, telephony repeat coils had to handle common-battery voltages and to minimize cross-talk when the circuits were combined in the "Phantom" arrangement described below.

The Solution to a "Catch-22"

Low-end audio response was needed for radio-program applications. But transformers that did handle the lower frequencies also exhibited an unacceptable 2 to 3 db loss in the voice-band. (Many early repeat coils used toroidal cores wound with silicon-steel wire in a coil that had a gap cut into it. One early version of this coil, Western Electric's "62-type" used an open gap. The coil was stable at DC and minimized magnetization, but it had poor low-frequency response.)

The "93-type" coil was developed with a powdered iron fill in the gap; this improved the low-end response. A further early iteration was the "173-type." The 193 and many later versions used a permalloy core. Most of the later coils had impedance ratios from 0.6:1 to 2.5:1.

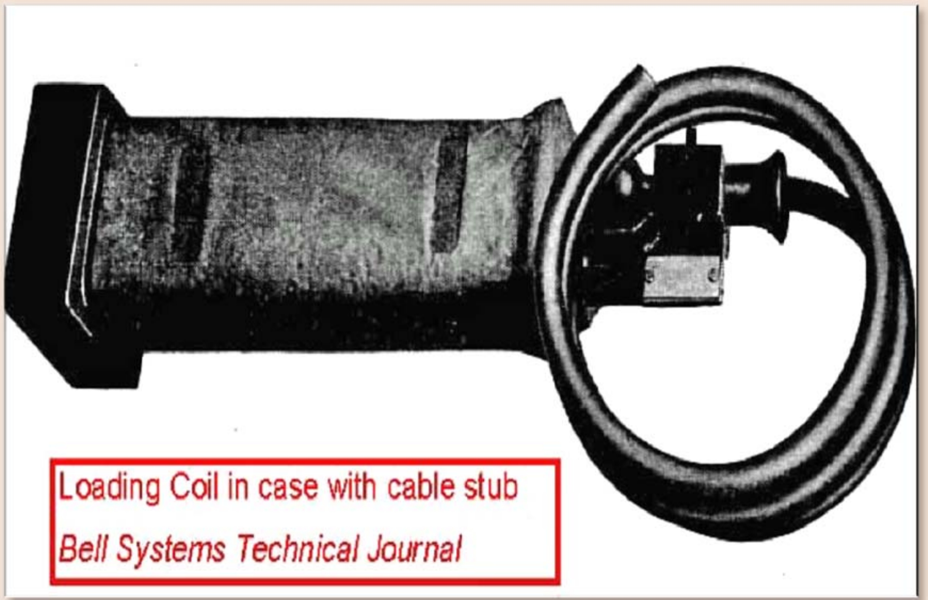
Good low-end response would have been necessary for another reason. In telephony the more efficient coils wouldn't pass the 20 cps ring-down voltage. The telephone company's answer to that one was to eliminate the problem: The introduction of the "composite" generator at the switchboards sent 135 cps down the line as ring-down voltage, instead of 20 cps.

There were many other transformers over the years, including the 119C, the 153A…and the venerable 111C. The matter of balancing transmission lines was perfected to the point that performance on a properly-installed wire pair approached design limits.

Loop Loss vs. Length: The Loading Coil

The phone company now had a dependable way to terminate both ends of a long-distance wire circuit and to balance that line. But loop-length loss remained a major issue. The physics of the situation meant that capacitance (and high-frequency loss) increased with distance. A partial solution to the problem of capacitance-limiting in passive circuits was Michael Pupin's "Loading Coil," invented in 1899 and further improved by Western Electric. Loading coils were, quite simply, series inductances added in the wire leg to minimize the shunt capacitance of the wire; thereby reducing line reactance and approaching a pure resistance.

In well-balanced circuits, loading coils were added to both legs, and to maintain balance, these load coils were usually wound on a common core.



Loading Coil in case with cable stub
Bell Systems Technical Journal

Program-audio Limitations

The loading coil and the self-impedance of the line together defined a fairly sharp cut-off frequency (and thus the pass-band of the channel.)   Practical loading coils delivered a useful pass-band…for voice communications. To extend frequency response, this loading was removed where possible from circuits used for broadcast audio.

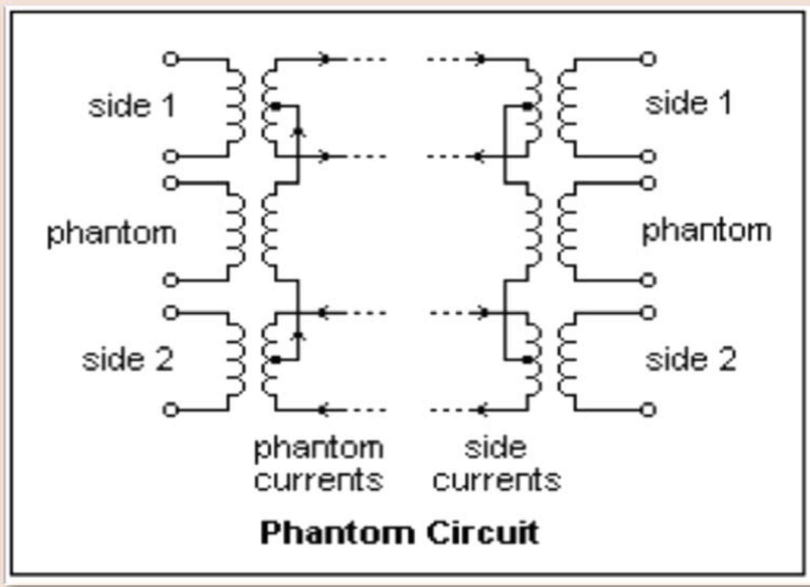
Another effect of line processing not noticeable until radio programming passed through, was that the cumulative effect of induction produced significant Group Delay in long-distance channels…what Fred Krock called “That Network Sound” *Radio World, August 17, 2005.*

Typical inductance of loading coils for early telephony was approximately 0.163 Henry, producing a pass-band of around 2400 cps for a ‘nominal’ loop-length (of course different wire sizes and lengths dictated different loading). It was obvious that open-wire lines, by virtue of their lower native capacitance, required substantially less loading than did cable. Open-wire loading was usually inserted at the transposition locations. Loading of *cable* pairs usually happened at wire offices or strategic splice-points in the underground system.

The Phantom

Once line-balancing had been “perfected,” engineers took advantage of this balance to extract something for nothing. The “Phantom Circuit” was a “free” channel derived from the center-taps of repeat coils on the ends of two closely-matched pairs.

The introduction of Western Electric's superbly-balanced 37-A repeat coil allowed Long Lines to develop the "phantom" circuit that provided a concurrent path for telegraphy or telephony. It was a fine trick, from the ingenious minds of engineers who knew their theory and knew how to implement that theory.



The two "main" circuits (ironically known as "side" circuits), together with the derived phantom are labeled collectively a "Phantom Group." The three circuits are essentially independent of each other, assuming line balance is good. (Line imbalances created cross-talk.)

Phantom Group *Loading* was the next challenge. Phantom group loading required different topologies for the "side" pair in a phantom circuit. This was necessary because off-the-shelf loading coils introduced unbalances into the phantom pair and negated the usefulness of the phantom. (Better-balanced loading coils were developed shortly after Western Electric's New York labs were opened.)

An interesting sidebar: Phantom circuits were carrying simultaneous voice and telegraphy on some routes. The 'clickers' were DC-against-ground and caused non-linear distortion in the audio. Engineers traced it to the DC current's momentary saturation of the repeat-coil cores. The effect was known as "telegraph flutter." Long Lines told the telegraphers they had to reduce relay current as a stop-gap, while designers went to work on a more stable loading coil, deployed around 1916. It was just their way of doing things…steady progress in a march to 'perfection.'

Documentation

To enforce the Long Lines requirement for standardization in the networks AT&T published a set of technical and operating specifications that morphed into the iconic "**Bell Systems Practices**." In 1922 the **Bell Systems Technical Journal** appeared, containing thoughtful and in-depth technical papers reflecting the cutting edge of the state of their art. Today BSTJ is available on-line, a treasure-trove of technical detail, written in the parlance of the day. Good reads. As you'll notice, we're extracting a lot of information from these papers.

As early as 1906 the Eastern half of the country had toll lines between every major city. Almost all the network was metallic but some thin-route rural services used power-line "carrier-current" as the "last-mile." This version of "carrier-current" referred to the imposition of an RF signal on the power line.

The State of the Wire Network

In the early 1900's almost all inter-city lines were open-wire. The original open-wire "104" (104 mm) was about #10-gauge. Western Electric now introduced the new "165" wire (closer to #8-gauge). The larger wire meant lower loss…but its impedance changes created a problem with existing loading coils; particularly in bad weather. Here's one of our more important visuals:

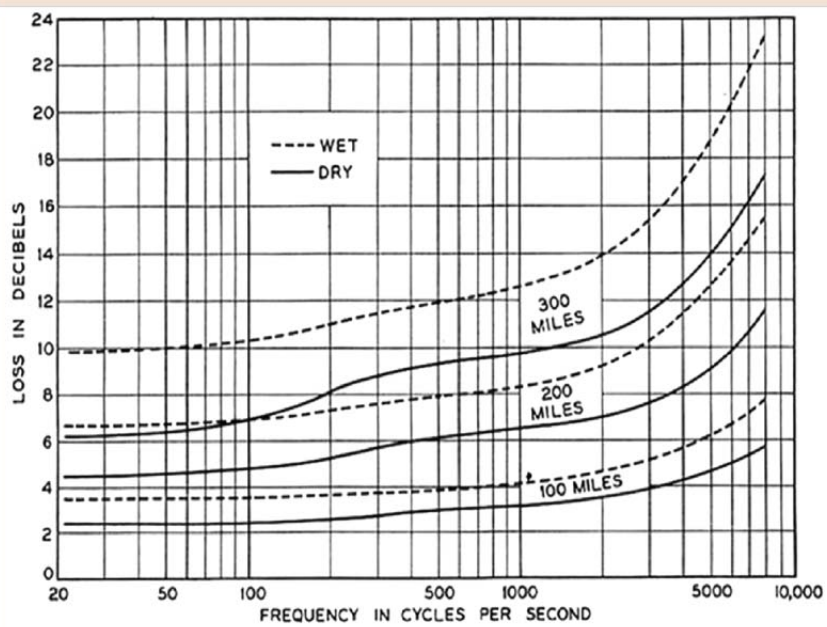
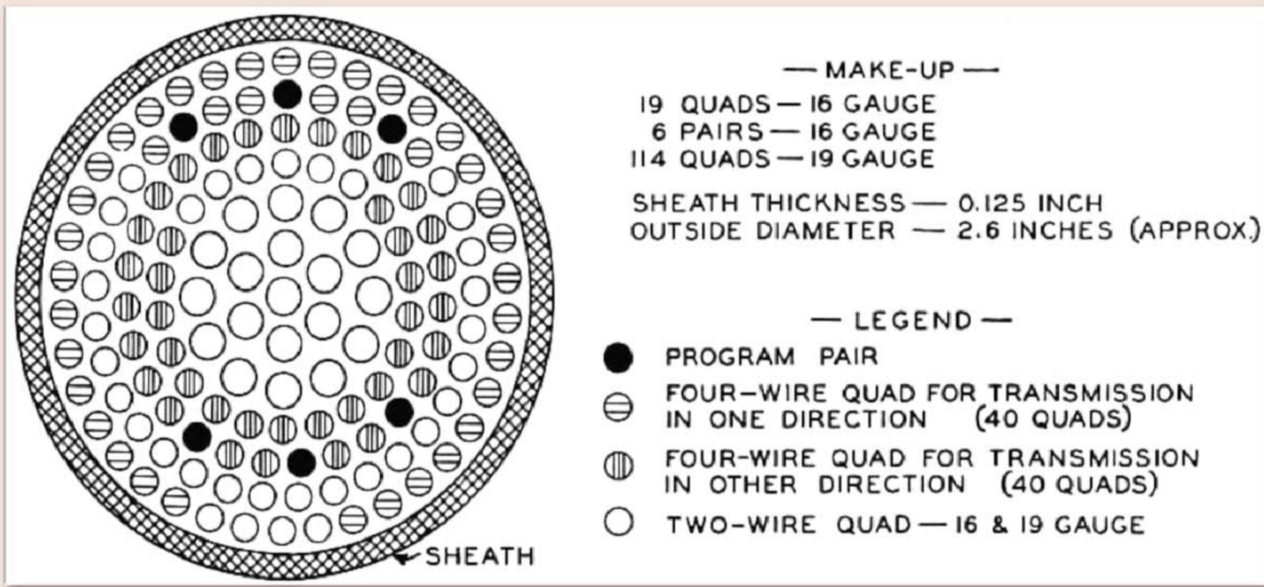


Fig. 2—Loss of 165-mil. 8-inch spaced pairs when inserted between 600-ohm resistances.

Bell Systems Technical Journal

The use of balancing circuits and the loading coil extended the range for telephony to hundreds of miles. Engineers were approaching the theoretical limit for long-distance reach. Given there were still no amplifiers, attention turned instead to developing even better wire. In the wire offices the engineers were now using 22-gauge "quad" entrance cables in which each set of 2 pairs was closely matched (shades of Cat-6!). Detailed work led to exacting specifications for pair arrangement, twist and insulation and capacitance uniformity.

This is a later version of what the cable looked like:



Deployment of this new cable also meant that Phantom Group Loading was more successful because of the more-closely-matched pair characteristics in the quad cable. While this made Phantom-derivation more reliable, Phantom circuits weren't as important in *cable* applications; additional circuits simply used additional pairs. Phantom circuits thus remained most popular in open-wire applications.

Buried Long-distance Cable

In 1914 AT&T Long Lines deployed the first quad-cable in a buried Boston-to-Washington route, as well as a successful submarine cable in Chesapeake Bay: a cable of 17-pair, 13-gauge paper-insulated wire, installed with two loading coil sets. The cable was a pre-built product that Western Electric was testing. (The first transcontinental buried cable wouldn't open until 1942.) Cable was more physically secure and subject to less temperature variation but the higher capacitance-per-foot meant more conditioning was necessary per unit length.

Further Improvements in (passive) Long-wire Transmission

In 1910 Long Lines had more than 85,000 route-miles; primarily open-wire…but still no amplification. Encouraged by the results from larger-gauge wire and working to meet the challenge of transcontinental telephony, engineers now approached the wire plant, section by section. Attention first focused on the New York-to-Denver segment.

"165" wire was installed between New York and Chicago in 1910 and in the installation, a better way of hanging wire was found. New (glass) insulators were developed and changing the wire hangers at the transpositions led to a reported 20-percent improvement in balance.

With 165-mil open-wire in use, attention turned to fine-tuning the Phantoms. Most of the problems were traced to poor (or absent) transpositioning of open-wire lines. (It seems 100-percent oversight of installation crews was necessary even then.)

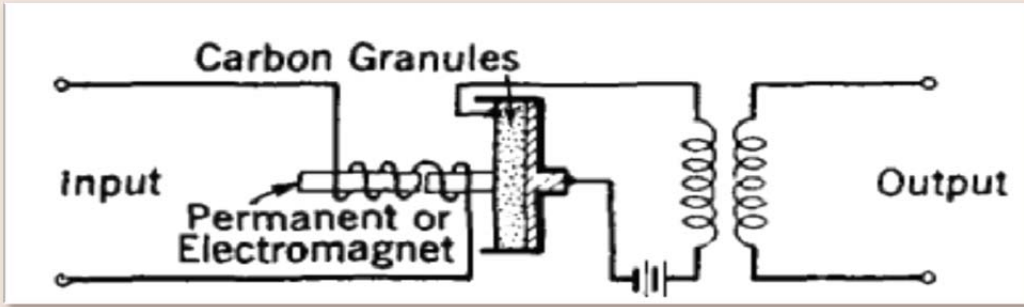
When finished, Phantom cross-talk on the Denver line measured 28.5 db; well within specified limits. This line segment was so good that it was specified as the test bed for the day the new "voice-repeating system" was brought into the field.

The Repeater

The voice repeater was an inevitable development. There was just too much need for it *not* to happen. Again, it took the intellectual energy and experience of AT&T to bring it into the practical world. Chief Engineer John J. Carty made some smart hires and turned the company's internal engineering focus to *science* research. One of his best additions was Physicist Frank Jewitt who had an inside track to the scientific community. Jewitt was considered a "star magnet" to the extent that very qualified scientists wanted to work with him. Arguably, Jewitt's best hire was Harold Arnold, a guru in Western Electric's research department.

AT&T issued a "General Repeater Study" in April 1911. It was essential a 'Call for Amplification-technology' and it brought inventors out of their basements. One of the 'inventions' under consideration for a few minutes was Thomas Edison's "reciprocal telephone repeater." That turned out to be nothing but a method of switching a wire pair between "talk" and "listen," and not a form of uni-or bi-directional linear amplification. It also required DC control voltages against ground.

In 1906 Western Electric brought out its own crude form of long-distance 'repeater' (the "Shreeve"). The Shreeve consisted of a powerful stationary field and a movable coil; it might be described whimsically as a "magnetic-field amplifier." The Shreeve was terribly inefficient, it got hot, and it only worked for short periods. It required non-loaded open-wire lines and Shreeves could only be operated in limited tandem. But it was the best they had at the moment.



Concept of the Shreeve Repeater

Loop tests were set up in the laboratories and the Shreeve became part of the "22-type" repeater scheme (2-wire, bi-directional). This repeater in fact was part of the backup plan in the event an inertia-less repeater wasn't developed by the deadline.

The British put forward what was called "The Electrophone System." An outgrowth of their approach to wired music distribution, it was essentially a loudspeaker activated by the incoming voice signal, whose sound carried to a diaphragm generating the relayed outbound signal. Terribly inefficient.

Mechanical repeaters had physical limitations that couldn't be overcome. Moving toward an inertia-less solution, the first *electronic* lab work was done on mercury arcs. Mercury arcs had severe non-linearity…and it was difficult to get the arcs *started* in the first place.

As cross-country wire improvements went forward and 1915 approached, engineers were preparing a back-up "non-repeater" plan…just in case. A non-amplified coast-to-coast voice system would work…but would require replacing open-wire spans with #5 wire (from 165 mm to 220 mm). On the other hand, engineers had calculated that if they found a suitable voice-repeater performing to AT&T specifications, the 165 mm open-wire line would work fine.

Now the scientists went to work alongside the engineers. (One wonders if this was when the white lab coat and pocket-protectors first appeared.) In setting the goals for a trans-continental voice system, a set of specifications for the working environment (i.e. the real-world impedances and line resistances) was created. The design team would work within these physical limitations.

The High-Vacuum Tube Repeater

Around 1912 Lee De Forest knocked on the lab door with his "Audion" tube. As developed by De Forest, the tube worked fine at low signal levels but crashed at higher levels (a blue haze appeared in the tube). AT&T scientist Harold Arnold immediately knew what was wrong: the vacuum tube wasn't sufficiently evacuated (De Forest thought too high a vacuum was detrimental). And his tantalum filament was puny when it came to electron emission.

Without explaining to De Forest how they would make the Audion work, AT&T quietly bought his patent rights, as well as those of others who had developed similar devices. Scientists and engineers then set about developing the "101 high-vacuum tube," and handed an early version of this tube to Western Electric for mass production.

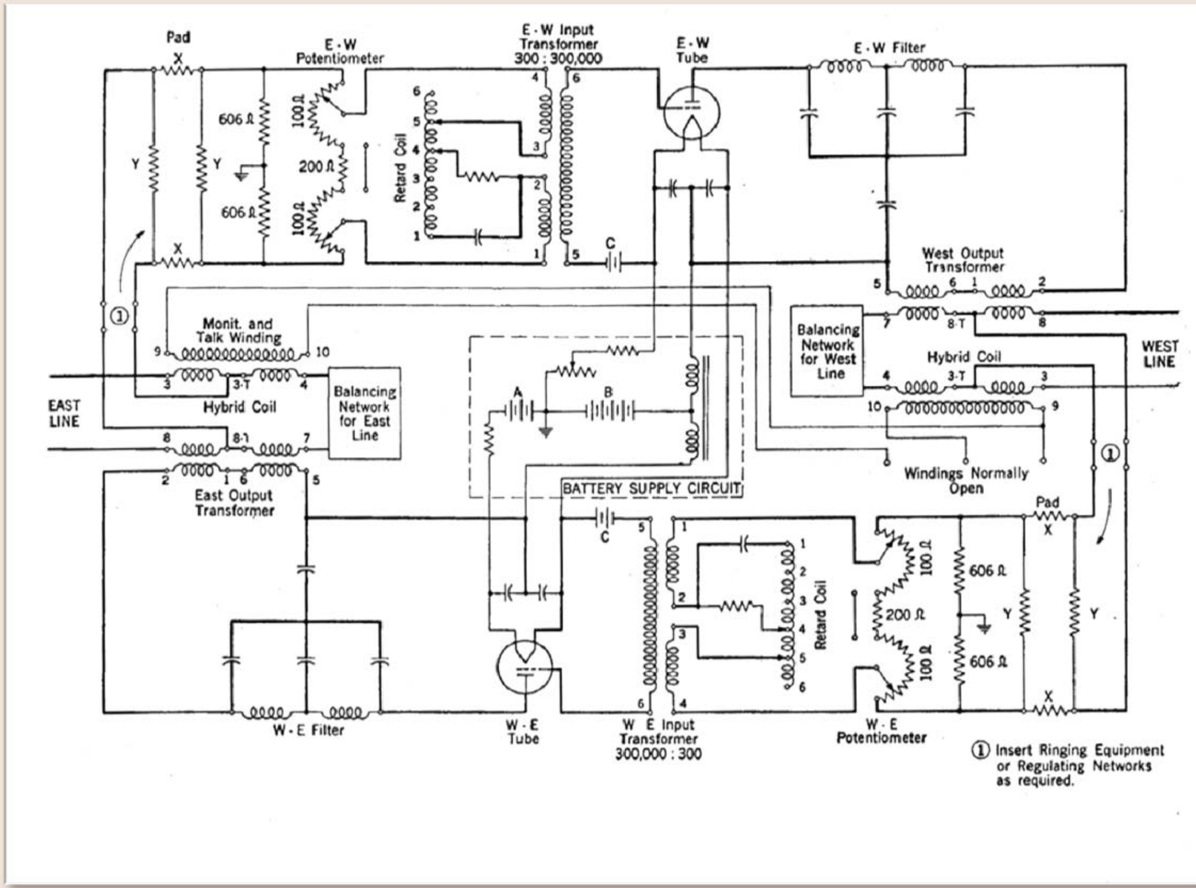
(Interestingly, this tube wasn't the first to reach production; that honor belonged to Irving Langmuir and GE, as well as to RCA. And the French and Germans were developing high-vacuum tubes along parallel lines.)

So I have to say…wait for it…"New developments don't necessarily exist in a *vacuum*."

The high-vacuum tube was another Disruptive Technology. All sorts of applications awaited mass production, from PA to sound-on-film to disc recording to radio to television. Western Electric couldn't turn out the tubes fast enough. The appetite for tubes in AT&T's network and the Radio Group's own play in the tube field led to patent-related litigation a decade later.

The Bi-directional Repeater

Once AT&T engineers had made the high-vacuum tube the heart of an amplifying system, they immediately applied it to long-haul telephony. Amplifiers were designed to provide 3 db to 30 db net gain through the voice pass-band. It was also obvious a transcontinental circuit had to accommodate many repeaters in *tandem*. So repeater stability was important; collated imbalances at several points would create ringing down the entire circuit.



The classic "22-type" repeater (2-wire, 2-direction) *Bell Systems Technical Journal*

Two-wire Repeater Theory

For bi-directional amplification on two-wire lines, the "send" and "receive" circuits had to be isolated by a factor greater than the amplification of the repeater, or feedback and 'singing' occurred. The practical two-wire repeater employed a form of Wheatstone bridge and required a balancing network identical in impedance to the connected transmission line (today we know this as a "hybrid"…see the "Balancing Network" in the photo above). In theory the 22-type repeater required a complex impedance; pragmatists, aware of the difficulties in field-adjustment, instead came up with an "average" network of three reactances.

The use of band-pass filters to narrow the useful voice pass-band added to the stability. Careful circuit design meant the wire paths could support phantom telegraphy, and audio could be dropped off at intermediate points.

The first test of the "high-vacuum" repeater took place on October 18, 1913. A repeater was placed in Philadelphia on the New York to Baltimore circuit. It worked; hundreds were ordered.

On January 25, 1915 Alexander Graham Bell sat before a telephone in New York; Thomas Watson, his assistant in 1876, waited in San Francisco.

Bell: "I have been asked to say to you the words you understood over the telephone through the old instrument: 'Mr. Watson, come here, I want you.'" From across the continent, Watson responded: "It would take me a week to get there now!" *Photo/quotes courtesy AT&T files*

The first transcontinental telephone line was crude, but it worked. It was a single telephone circuit. But it was exactly what AT&T needed to legitimize its telephony efforts.

The measurements on the first, carefully-tweaked transcontinental telephone line:

Overall length:	3,359 miles
Total Bare-Line losses:	53 db (dry weather)
Equipment Insertion Loss:	7 db
Frequency response:	350 to 1250 cps *+/- 10 db*!
Total Repeater Gain:	40 db (6 repeaters)
Delay:	.067 seconds

The next step was to achieve transcontinental transmission on “ordinary” non-loaded 165 mil lines. It had been discovered that loading of these circuits produced unsatisfactory delay and consequent echoes. World War One held things up for a while; then in 1919 a non-loaded circuit of vastly improved performance was successfully tested between New York and Chicago.

From Chicago west, circuits received the benefit of several related improvements in terminating and balancing technology; even Group Delay equalization was addressed. By 1920 trans-continental circuits were no longer ‘one-of-a-kind.’ The new wire paths had twelve repeaters with an end-to-end loss of no more than a dozen db, using non-loaded pairs in a combination of cable and open-wire 165 mm plant. Audio response was also improved.

The new “standard” 16-gauge *cable* had a cable capacitance of .062 mfd per mile. For program use these cable pairs were loaded with 22-millihenry inductance coils spaced 3,000 feet apart (telephony voice-grade circuits used loading coils spaced 6,000 feet apart). This delivered path loss of about 0.25 db per mile. (Designers even worried about temperature changes in the loading coils and shielded them as much as possible, packaging them in groups as we’ve noted.)

Loading and Group Delay

The arrangements used for practical circuit loading created some nasty frequency-dependent delay characteristics; typically, lows were delayed more than high frequencies (due to the loading inductances). Initial compensation included adjusting the value of series capacitors so the circuit delay was lower at low frequencies.

Delay Equalizers

Western Electric then added a further refinement: “The velocity of transmission through a loaded cable decreases as the frequency is increased toward the cutoff point of the loading. To neutralize this effect, delay-equalizing networks are inserted in the circuit.

“(These) retard the lower frequencies, thus equalizing the velocity of transmission through the combination of cable and networks for all frequencies in the band to be transmitted.

“With the greatest length of cable circuits which will be used in this country for program transmission, this amount of deviation per section is not sufficient to cause objectionable distortion. For a 50-mile section uncorrected, the delay at 8,000 cycles was 0.9 millisecond greater than at 1,000.” *Quotes, photo: Bell Systems Technical Journals*

Total delay was now kept within “reasonable” limits: “With 40 amplifiers in tandem, the overall delay at 35 cycles is 75 milli-seconds greater than at 1,000 cycles, while there is no appreciable difference between the delay at 1,000 cycles and the delay at higher frequencies.” *Ibid*

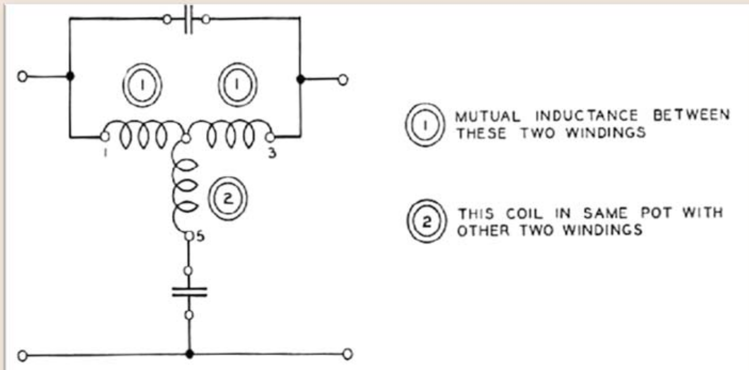
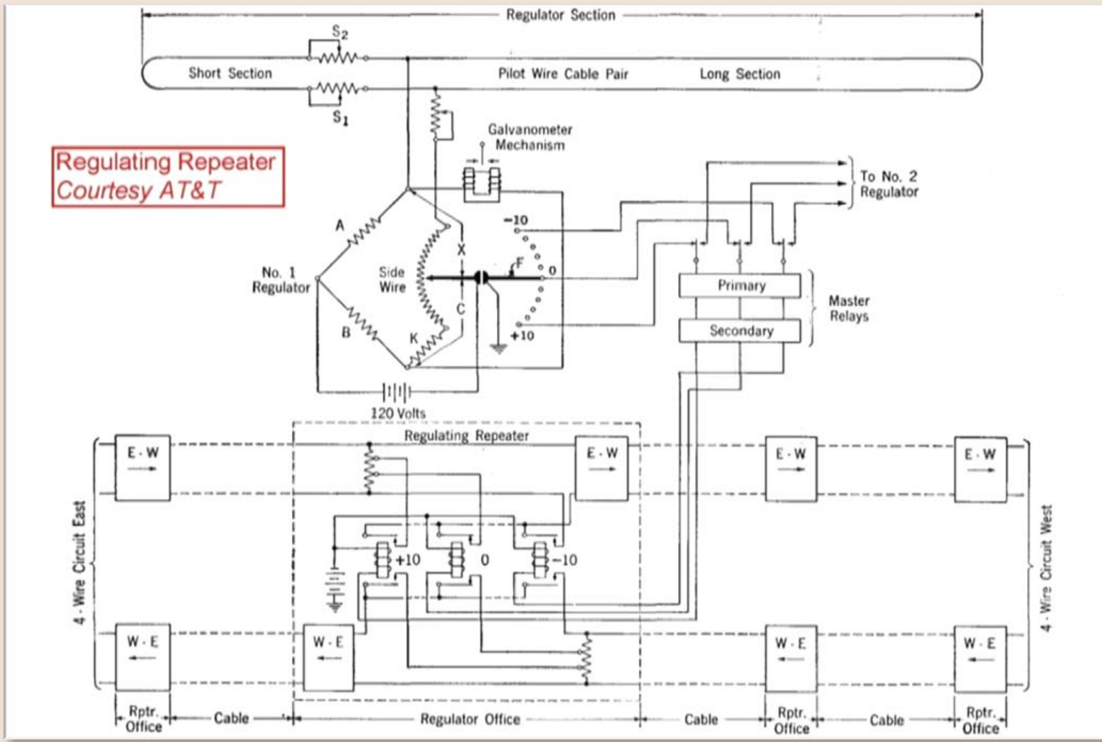
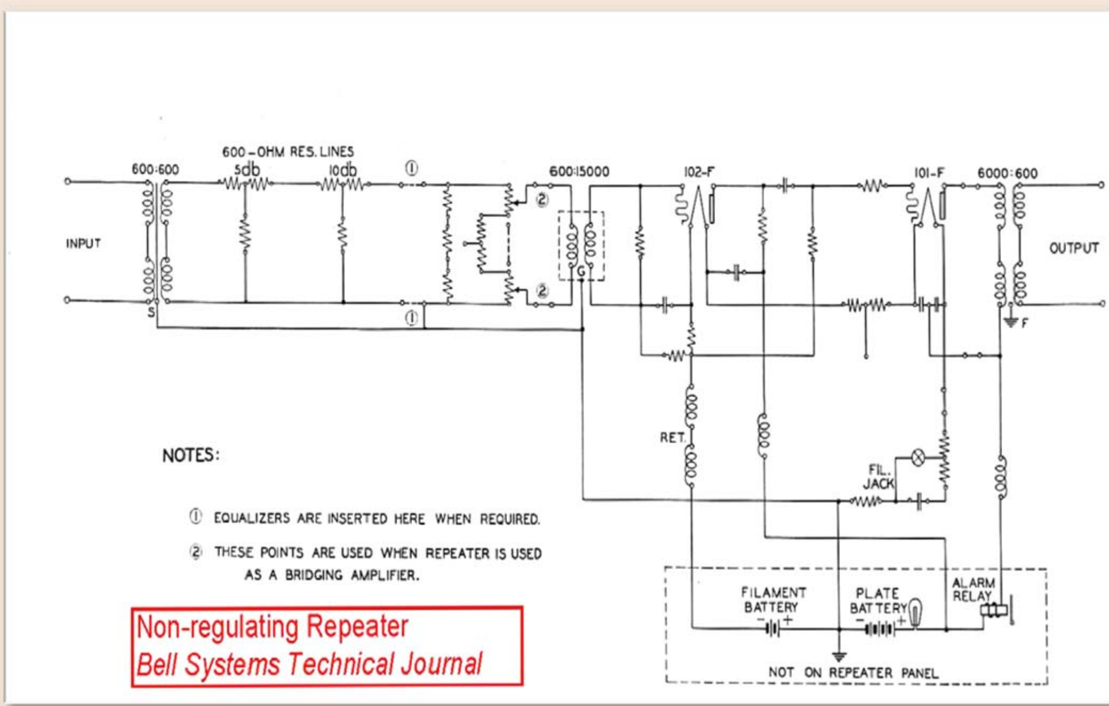


Fig. 20—Schematic circuit of section of delay equalizer. For a 50-mile equalizer, three kinds of sections are used which vary in the resonant frequency and in the sharpness of resonance. The first three sections are of one kind, the fourth is of another and the last seven are of the third kind.

By the early 1930's much of the outside plant was cable and there were two classes of repeater in use: "*Regulated Stations*" and "*Non-Regulated Stations*." The non-regulated repeaters were fixed-gain, preset during line-up. The regulated stations had remote-operated gain controls controlled by a master pilot-tone voltage, itself a derivation of path performance measurement. Automatic regulation was necessary to compensate for tube changes and for cable-loss variations with temperature. Over a temperature range of 55 F to 109 F (not uncommon in the West) as much as an 18db change at 100 cps was seen; at 1000 cps the delta reached 28 db. Compensating for these changes in wire offices across the country was a task beyond the capability of operating staff; hence the deployment of the (automatic) Regulator:



"Non-regulated" repeaters were used in areas where weather variables were of little impact:



Pre-distortion

Again, from the Journals: "The means utilized to accomplish the pre-distorted transmission… includes the provision of a so-called pre-distorting network at the sending end of a program circuit, and a restoring network in each branch which supplies a broadcasting station. The pre-distorting network introduces a large loss at low frequencies with a decrease in loss as the frequency is increased. By introducing suitable amplification immediately behind the pre-distorting network, the resultant effect is to raise the high-frequency transmission relative to the low-frequency transmission by the difference in loss between the 1,000-cycle loss of the pre-distorting network and its higher frequency loss. The restoring network characteristic is the inverse of the pre-distorting network." *From Bell Systems Technical Journals*

Long Lines Test Board 1920s
Courtesy AT&T

Long Lines network improvements continued; it was in the AT&T genes. The process of perfection had been going on for nearly 20 years when AT&T turned its attention to the new "radio broadcasting" opportunity. While AT&T was mastering the art of broadcast-program wire-transmission, it was using that same technology to exercise its licensing for Toll Broadcasting. Those efforts would have an advantageous outcome for AT&T.

CHAPTER THREE

AT&T and "The Wireless"

AT&T's development teams were watching wireless advances with an interest in extending telephony to areas impractical to reach by wire. AT&T wasn't the earliest wireless pioneer, but the company brought its culture to investigating and applying wireless to wire and, in so doing, advanced the state of the art. It's instructive to see how their wireless work led to the company's "experimental" foray into broadcasting.

In 1885 Thomas Edison demonstrated a "wireless" telegraphy link that worked by induction: moving trains passing through railway stations changed the flux in a loop surrounding the tracks for the short time the train was moving through the station. As usual he filed for a patent; Marconi…just in case…bought the patent in 1903.

Marconi found his early market in business communications and in servicing ships at sea. By 1900 most vessels had a 'radio shack.' In 1901 the American Navy gave up its visual signaling and carrier-pigeon techniques to try radio, and several of the Hawaiian Islands adopted radio for inter-island telegraphy. By 1903 trans-ocean telegraphic messages were commonplace. Two years later the Russo-Japanese War was reported by radio-telegraph and in 1904 the U.S. Weather Bureau adopted wireless to disseminate weather information.

Many marveled at the wireless as 'the greatest of all electrical mysteries.' Machinery Magazine tried to explain, concluding: "From the foregoing…it will be seen that there is nothing mysterious about the operation of wireless telegraphy; it simply consists in using, for a sending instrument, a device that is capable of emitting electrical radiations and for the receiving instrument a device that is acted upon by these radiations." This rather grand explanation is followed by an opinion: "The possibilities of wireless telegraphy have been greatly exaggerated by the sensational press. It has been asserted that it would supersede the present methods and that before long messages would be transmitted across the Atlantic and that many other impossible things would be done. As a matter of fact, however, wireless telegraphy is limited to a certain sphere…any receiving instrument placed within the range of the transmitter can receive the signals; hence there could be no privacy." *Machinery Magazine, November 1899.*

RCA Communications jumped out front in the business of international messaging, with its fabulous East Coast landing stations. Development was funded by large-scale users like United Fruit who saw the potential in continuous messaging contact with their world-wide enterprises.

You'll note from this ad that the company was also offering hardware and systems. One wonders if live mules were provided as part of the "portable" pack sets.

The Privacy Issue

Gugliemo Marconi lent the status of his reputation to the belief that wireless messaging was secure. He naively believed that sharp tuning would keep messages from being 'overheard' by those with wide-band receivers. The Emperor was disrobed in 1903. Marconi scheduled a demonstration for Carnegie Hall. That demo was hacked, by a fellow named Nevil Maskelyne.

Maskelyne interrupted the proceedings with a nearby transmitter and inserted his own messages. Marconi was privately furious but refused to respond to newly-minted doubters. Senatore Marconi had a blind spot. But still, wireless was capturing the imagination. Mary Bellis explains: "In 1910 Marconi opened regular American-European radiotelegraph service. (Anecdotally) several months later the…radio service… enabled an escaped British murderer to be apprehended on the high seas. In 1912, the first transpacific radiotelegraph service linked San Francisco with Hawaii". *The Invention of Radio, Mary Bellis*

Limitations of Radio-telegraph Communications

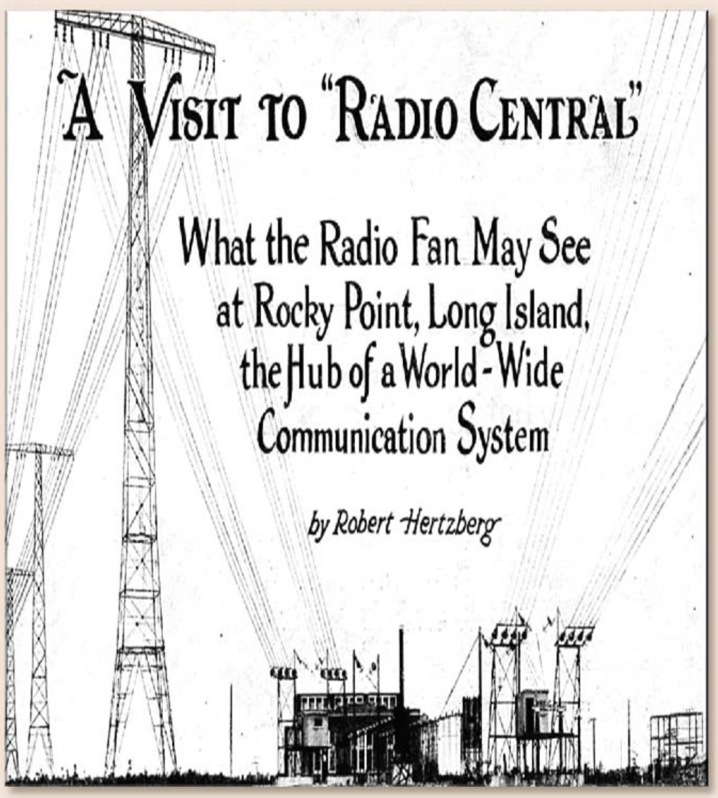
The early Spark-Gap transmitter and the coherer receiver operated at very slow speed and required manual intervention (one had to continually reset the detector). It took the development of the continuous-wave (CW) generator by Alexanderson and the implementation of high-power high-vacuum tubes to provide practical signals. Radiotelephony came of age rather quickly. The Long Lines Department began interfacing wireless equipment with the telephone network. Western Electric meanwhile began to develop and manufacture radio broadcasting *equipment* that would be used in this new area of applied engineering.

The big goal now was to cross the Atlantic with the human voice. "Radio-phone" tests began off Long Island with arguably the world's first high-power vacuum-tube transmitter. "It was from (the famed Naval station) NAA (in Arlington Virginia) that the human voice first leaped the Atlantic…early in that morning of October 22, 1915, a little group of Naval officers and others were routed out of bed to be told that they might hasten to Arlington and from there talk to other Americans in the Eiffel Tower, with the bustle and roar of a thousand guns only a few miles away from Paris, and the Tower itself used as a target now and then in the daytime. They talked (in Arlington), and were heard in France, (in the Canal Zone) and at Pearl Harbor in the Hawaiian Islands." *Newsmagazine article: "NAA" by Donald Wilhelm*

And if you want some cocktail party trivia, the words memorialized in this first transatlantic connection were “Hello Shreeve!” So that you appear cutting-edge in your conversation, you’ll add that “Shreeve” was H.E. Shreeve, a young Bell company engineer given the dubious task of hanging out at the top of the Eiffel Tower, waiting for the signal. (One wonders if this same ‘Shreeve’ was dabbling in mechanical voice repeaters.)

Reflecting AT&T’s strong interest in integrating telephony with wireless, an experiment was set for the late evening of January 14, 1923. Specially-equalized lines connected AT&T’s NY headquarters with RCA’s Rocky Point transmitter. AT&T historians record the following conversation as the terminal was being readied for the trans-Atlantic test: “AT&T’s Vice-President Carty, who had remarked…after giving some final instructions: ‘Now I'll get a little nap.’ ‘What!’ said the astonished Publicity Manager. ‘Aren't you nervous? Can you really sleep?’ ‘There's nothing to worry about,’ was the answer. ‘The tests are what I expected. There was sleet on the wires (when) we opened the first transcontinental line, but I slept, on that very sofa, for 30 minutes. You see, I knew that line was being watched—by telephone men.’"
Commercial Broadcast Pioneer: The WEAF Experiment 1922-1926; Banning

America was now in voice contact with the world…and the world had grown a little smaller.



RCA Journal

Thin-route Communications

A less-romantic application was the extension of short-hop telephony to locations where wire circuits were impractical or too expensive (scarcely-populated targets or places impossible to reach by practical wire runs). AT&T installed its first full-time point-to-point radiotelephone link in California. "…the first use of radio telephony for (dedicated) public service…was a radio link which went into service July 16, 1920, between the town of Avalon on Catalina Island in the Pacific Ocean, 30 miles away from the California mainland…and a land station at Long Beach where junction was made with the wires of the Bell System. The transmitters had a carrier output of about 100 watts, and two-way communication was obtained by using two frequencies—638 kc from California to Catalina, and 750 kc in the opposite direction…

…A cable to carry the traffic from the island to the shore (owing to conditions growing out of the war) could not be manufactured as soon as required. Radio was therefore turned to because it could be made available promptly." *Commercial Broadcast Pioneer: The WEAF Experiment 1922-1926; Banning*

This radio link lasted three years and spawned many other short- and long-hop telephone-radio links around the world. Notable for a permanent long-distance telephony link was the connection between Seattle and Juneau Alaska. Full-time radio-telephony to Hawaii was turned up in 1931 and Tokyo's connection made in 1934. The trade magazines reporting each achievement predicted a future 'made brighter by the combination of land-lines and radio.'

In October 1922 Westinghouse, through its own wireless development teams, scored a little-known coup when they provided the first Trans-Atlantic radio "remote" from London to new station WOR in New York. This accomplishment presaged the massive use of radio links from the European Continent in the warm-up to World War Two.

New Kewl Audio Processing

Now some new acronyms entered the language through the Bell Systems Technical Journals, describing solutions to the problems created by passing voice through a non-linear medium. First: VOGAD. In operation 60 years before Star Wars appeared, VOGAD stood for **"Voice Operated Gain-Adjusting Device."** VOGAD used VARIO, a **"Variable-Gain Amplifier."** It was arguably the world's first gated, program-controlled AGC. It featured a "Gain Increaser," a "Gain-Increaser-Stabilizer" and finally a "Gain-Decreaser." (Those who developed the CBS Audimax with its "Gated Gain Stabilizer" and the many other processors that have populated the modern age may have found their initial recipes in the Bell Systems Technical Journals.)

In order that the voice-operated switch didn't lock up when channel noise overrode speech audio, CODAN was brought to the rescue. CODAN meant **"Carrier Operated Device Anti-Noise."** It was essentially a carrier detector: no signal; no audio.

To keep CODAN honest in the presence of varying signal strength, a mechanical contrivance sensed both signal and noise levels and opened the circuit only when the signal was stronger than the (band-pass-filtered) noise. This lash-up also functioned as a carrier-sense gate.

Next came **Compandors**; also ahead of their time. The companding system wasn't absolute in its action; instead its time constants were designed to approach those of syllabic rates and repetition. These early compandors were successful in passing intelligible speech while adding 25 to 30 db to the S/N ratio.

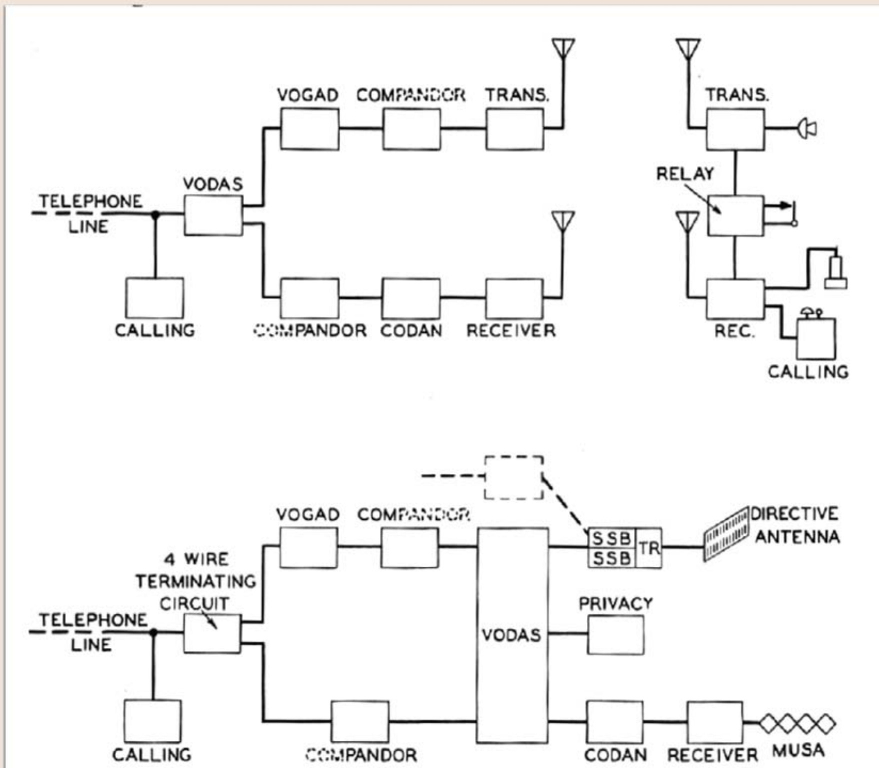


Fig. 5—Three arrangements of radio terminal apparatus are shown herein.

Bell Systems Technical Journal

Like everything else AT&T faced, noise was a problem to be solved in a straightforward fashion. Their design and applications teams were unmatched; they continued to "write the book."

Undersea Cables

Long Lines took a similar approach to undersea-cable transmission. Details on submarine cables will be the subject of a revision of this "book." Not surprisingly, the same AT&T problem-solving teams mustered on deck to make those cables work.

We will observe the telephone company moving into radio broadcasting with the same, methodical, deliberate problem-solving approach…though the denouement of *that* venture might have been beyond their plans…

The Earliest "Broadcasters"

AT&T wasn't the first to enter the broadcasting field. Following the corporate re-organization around 1907, the company's focus had been on telephony, and none but the futurists of 1907 had dreamed of sending a voice *beyond* the ear pressed to the far-end telephone instrument…much less than to more than one simultaneous listener.

Our story will now benefit from reviewing some lesser-known milestones in the early implementation of what became "radio broadcasting." Prior to the U.S. Government's imposed ban on radio during World War One, the records suggest the following:

> In 1897 a workable wireless transmitter was demonstrated at the University of Arkansas; it became station 5YM in 1912.

> In the fall of 1898, Notre Dame professor Jerome Green sent telegraphic messages a distance of about a mile, from Notre Dame to St. Mary's College. Other claims notwithstanding, this purportedly was the first transmission of any significant distance in North America.

> In 1900 University of Wisconsin professors and students begin experimenting with radio transmission using spark transmitters. Their apparatus was assigned the call letters 9XM; that station became the famous WHA. By 1915, 9XM was broadcasting daily reports for farmers by code…transmitting to grain elevators. Code-savvy receiver operators transcribed the information for posting to the elevator's bulletin boards. (It's another example of one communication medium being enhanced by a second…in this case wireless information becoming the printed word.) 9XM also transmitted music to Great Lakes shipboard operators, asking them to report what was heard.

> 'Tuning' the receiver of the early 1900's, one typically heard nothing but the sound of spark gap and arc-generator Morse code…different speeds, different intensity. Crude ciphers now protected confidential messages. Then in 1900 Canadian-American physicist Reginald Aubrey Fessenden purportedly spoke some words into a telephone transmitter: "One, two, three, four, is it snowing where you are Mr. Thiessen? If it is, would you telegraph back to me?" Mr. Thiessen, one mile away, heard the transmission.

Reginald Fessenden at his “computer”   *Source unknown*

> The history books suggest that on Dec. 12, 1901, Marconi claimed to have heard the letter "S" transmitted by Morse code across the Atlantic. Fact-checkers have since concluded that this reception was probably not possible and that Marconi may have heard static caused by lightning.

> In 1902 a fellow some consider the real “Father of Radio,” Nathan Stubblefield, lit up a wireless telephony link from shore to a boat on the Potomac.

In developed countries there was considerable amateur experimentation; almost all in Morse code: weather, farm and stock reports. Here and there a voice made it through the ether.

> Supposedly the first broadcast of voice intended for *general consumption* was heard on Christmas Eve 1906. According to legend, that same Audrey Fessenden transmitted voice programs from Brant Rock Massachusetts including a speech, an invitation to report on reception, and a phonograph recording. A second broadcast occurred New Year's Eve 1907. The claims are anecdotal. But the fact is someone had to be first, sometime.

And now our first comment/update received just prior to publication. James O’Neal writes:

“This is the reference to the Fessenden 1906 "Christmas Eve" broadcast.

As you may know, I've spent many hundreds of hours over the past seven years in trying to get to the bottom of this story and can truthfully say that based on all of the documentation I've examined it has to fall strictly into the myth category. Other that Fessenden's 1932 "deathbed" letter, everything points totally away from it having ever happened. (Sterling and Halper drew this conclusion too, as did a couple if other researchers back in the 1956 timeframe [50th anniversary of the supposed "broadcast'].)

“I would respectfully ask that you consider reporting what is documentable in this area--that Fessenden did do what can be considered to be the world's first broadcast in 1906, but this was a demo of radiotelephony that took place on Friday Dec. 21 instead of Monday Dec. 24. A big pile of records supports this. Also, you mention a 1907 New Year's Eve "broadcast." Typo? Fessenden only claimed Christmas Eve and New Year's Eve 1906 in the 1932 letter.”

Thank you James. This is a perfect example of the dialogue we hope to stimulate…and your own responses are encouraged. Onward:

> In the October 1922 edition of Radio News Charles Gilbert, a spokesman for the De Forest Radiotelephone and Telegraph Company, recalled: "The first actual application of the De Forest radio phone in reporting a news event was no doubt the reporting of the yacht races on the Great Lakes in the summer of 1907; Gramophone music was furnished between the spoken bulletins.”

Further from Mr. Gilbert: "The spring of 1907 saw the radio distribution of synthetic electrical music, generated and played in a building at the corner of Broadway and 30 7th St., New York City. The plant itself consisted of many inductor alternators whose frequencies were those of the entire musical scale.

Music furnished by this electrical organ was transmitted by wire to nearby theaters, hotels and restaurants, where…loud horn speakers poured into the ear this new electrical music.

“To connect this musical current into radiofrequency and impress on the antenna, which was erected for this purpose on the roof of this building by Dr. De Forest, was comparatively simple, and thereupon the demonstrations were made for the receiving stations in New York City. The experiment in broadcasting however, lasted but a very short time." *Radio News, October 1922*

> Around 1909 Lee Deforest established an experimental voice station, 2XG in the Bronx. Harriet Blatch, De Forest's mother-in-law, spoke in favor of women's suffrage; De Forest claimed this was the first ‘propaganda broadcast.’

> We can reliably trace the beginnings of *scheduled* radio broadcasting in this country to April 1909, when Charles Herrold began to transmit voice programming from San Jose California.

Herrold's station.   *No picture credit available*

Had Herrold stayed on the air regularly his would, without a doubt, have been credited as the first broadcasting station in this country. His interim operation used experimental call letters FN, 6XE, 6XF and SJN. The station later became KQW and, in 1949, KCBS.

Meanwhile, in 1914 and 1915 at the G-E Labs, Alexanderson and Colpitts were demonstrating voice modulation on carrier. At the same time the Hartley oscillator came to life. These developments kick-started radio-telephony in the Bell laboratories and in 1915 the first workable two-way voice link was brought up using low power (15 watt) tubes. (At the same time as we noted, tube developers were cobbing up parallel circuits that allowed power summation, and larger, higher-power tubes enabled the first try at long-distance radiotelephony.)

Experimenting continued:

> What would become WGI in Medford Massachusetts began life as 1XE in 1917, formalizing voice experiments that began in 1916.

> The Deforest station broadcast the Presidential election reports in 1916.   By now others (in Minnesota, Kansas and Texas) were making news with their telegraphic information services.

> On January 1, 1918 President Wilson's historic address to Congress explaining his "Fourteen Points for a Just Peace" was disseminated throughout the world by Morse code wireless, in just a few hours. (This was not a true "broadcast" in the sense that the information was sent through a lot of relays.)

> 6XD came up from Los Angeles in April 1920, beating KNX (nee 6ADZ) which came on the air in September 1920. (6XD became KOG in 1922.)

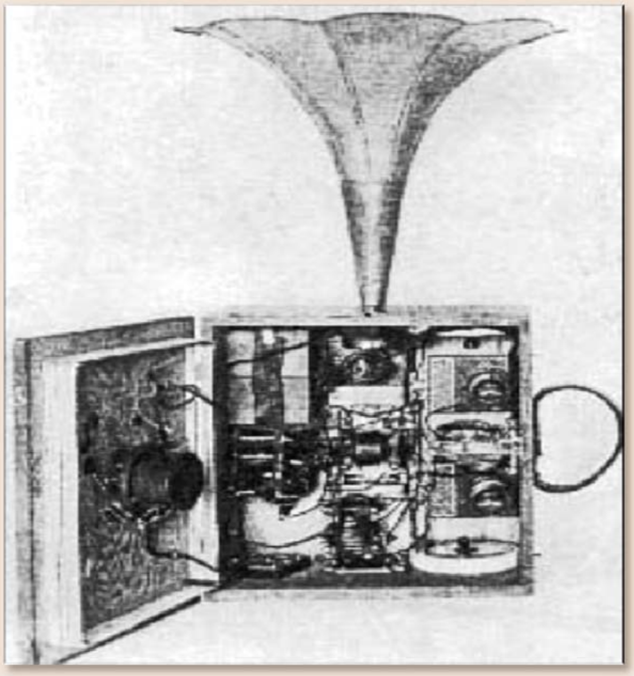
> XWA in Montreal was broadcasting in May 1920 and claims to have operated “the first scheduled broadcast in North America” (it became the famed CFCF).

But formal broadcasting history seems fixated on November 1920 when KDKA broadcast election results. The Pittsburgh station had been testing as 8XK and 8ZZ and in October 1920 received the KDKA call letters. And so, the famous November 1920 “first” broadcast.

Westinghouse was not the only station broadcasting the election returns that night. The Detroit News station 8MK (next WBL, now WWJ) was doing the same. In fact, 8MK had been broadcasting according to some reports as early as 1916, and came on the air with scheduled broadcasts on August 20, 1920…three months ahead of KDKA.

The “Radio” Receiver

KDKA and the earlier stations had been what AT&T called “experiments.” The receiving component didn’t even have a name at the time; Sarnoff had called the *concept* a “Radio Music Box.” In 1920 the National Bureau of Standards waxed poetic about one of many new reception devices: “The ‘Portaphone’ opens up many new possibilities. For instance, at 8:30 o'clock each evening a central station might send out dance music from its transmitting apparatus and those who cared to dance could set up their Portaphones on a table, turn on the current and have the music furnished sufficiently loud to fill a small room. Or in the morning a summary of the day's news might be sent out to be received by a Portaphone and digested by a family at breakfast, in which all could participate whether paterfamilias had the paper or not…The capacity can be adjusted to tune the apparatus to the required wave-length. The receiving set makes use of a vacuum tube detector and a two-stage amplifier, all operated by dry cells.



Portaphone *Radio News 0820*

"The signals are passed on to a special loud-speaking telephone to make the vibrations audible, while the large horn reinforces the sound waves until they completely fill a small room. The instrument as constructed at present has a range of about 15 miles, or well within the limits of an ordinary city…So far the only application of the Portaphone has been purely experimental at the Bureau of Standards, but it presents interesting possibilities for more general and utilitarian applications. A similar device with a larger coil has been built there…which develops sufficient power in connection with a transmission source to reproduce music loud enough to fill a very large room suitable for dancing." *Technical News Bulletin of the Bureau of Standards*

Lack of Regulation

From the 1900's onward, wireless had been a case of "let's see what happens." The American government stood by…while at the same time encouraging private enterprise to build up the infrastructure (at its own risk of course). A form of government control *was* instituted around 1910 and, while some of those laws framed legislation, the 1910 regulations had no teeth.

It's beyond the scope of our story to rehash the well-known history of radio regulation, de-regulation, anarchy on the airwaves and the government's feeble attempts to get its hands around something few at the time understood. It should be pointed out however, that radio broadcasting development cast aside the usual business architecture (the common belief you had to develop *standards* before manufacturers invested in equipment design).

In this case the genie let out of the bottle was simply too overwhelming to stuff back in, and it's easy to understand why radio grew the way it did.

Two factors hindered radio's early progress in developing countries: most citizens could not afford receivers…and there wasn't always an adequate power grid nor were there the mechanical resources necessary to support high-power transmission. In developed countries however, radio's explosion took place at exactly the right time…the Roaring Twenties. Citizens were ready for this new form of mass media.

AT&T is Still "Thinking" about Radio

Inside AT&T there were evolving opinions about "broadcasting." The culture of the company influenced the dialogue of course; some thought radio would defocus the company. For the true believers, there were approval bulwarks to be breached but fortunately some of the Believers had offices on the higher floors. Moving into a new business was a complicated procedure typical to large corporations. It required careful step-by-step analysis…followed by more analysis and more evaluation and risk/reward judgments.

At AT&T some were willing to stake their reputations on a "go" decision. But the company had a lot of fish in the skillet. Long Lines was dealing with an exploding demand for long-distance telephone circuits. Additional transcontinental lines were needed, as were submarine cables. Wags thought 'it was difficult enough keeping ahead of traffic projections for the *telephone* network. And now some Ivory Tower mercenaries wanted to add broadcasting to the mission!'

The prevailing mindset at AT&T was that if the company stepped into radio, the end game had to be in keeping with AT&T's policy of reaching the entire country. The company also believed its public-service obligations mandated *responsible exercise* of what it viewed as its *exclusive license* to control several of broadcasting's components. Finally, there was the primal need to control any business in which they participated.

The need for a decision gained momentum when engineers reported that the broadcasting spectrum was becoming hopelessly crowded. This implied that the "radio" idea was wildly popular…*and* that AT&T was running out of time.

One strategic question still kicking around the boardroom was how the company's existing wire network could best be used to develop broadcasting. Actually that activity was underway. While high-level planners were thinking at a 'national distribution' level, local phone companies were independently providing special connections to some radio stations…for "**NEMO**s."

NEMO: Anecdotally**:** "**N**ot **E**manating from **M**aster **O**perations" (or: "**M**ain **O**ffice")

According to some, NEMO is not an acronym at all. NEMOs were radio "remotes" (known then as "Remote Control"). Prior to the advent of short-hop radio links, the only way to connect a remote broadcast site to a radio studio was via a telephone line.

By the early 1920's the provisioning of these services had its own protocol. In metropolitan areas Bell companies placed special 'low-cross-talk' cable from the "Toll Board" (switch center) into the radio stations. Upon receipt of a "Remote Control" order, the telco extended what was called a "lateral" from the intended remote location back to the wire office, and then cross-patched this "lateral" to the already-established loop to the station.

Circuit Line-up

To test the line end-to-end, the installer cranked a magneto causing a ring-down drop to appear at the station's board. The station engineer who answered was asked to test the circuit. He would first zap the line with 110 volts from each side to ground. The installer then shorted the pair at the remote location and the station engineer observed line resistance (hopefully this was done after the 110 volts was removed). Next: a noise test…performed by the station engineer with headphones! If all was 'quiet,' the line was accepted and 'red-tagged' at the Toll Board against inadvertent 'man'-handling (there were no women in the switch centers at the time).

The first "Equalizers" were designed to flatten the frequency response of the line by reducing low frequencies only; then amplifying the result. The classic equalizer consisted of a variable resistor in series with a coil/capacitor combination across the line, placed at the receive end. Values in use on typical 600-ohm lines included a 250-ohm resistor, a 5 mhy tapped coil and a 0.04 to 0.2 mfd. capacitor. Plus some gain if available.

A version known as an "active equalizer" amplified the high-end only (active boost, shelving at around 4000 cps). The British used both approaches and simulated the necessary complementary line impedance in the feedback loop of an amplifier. These corrections of course had a limit; amplifying high-frequency response also brought up line noise.

KDKA pioneered in Remote Control; its 1921 firsts included the first church broadcast (Jan 2), first prize fight (April 11), first broadcast from a theater stage (May 9), the Davis Cup matches and a baseball game (August). How did they do it under the noses of AT&T? One reason was great relations with the Bell subsidiary serving Pittsburgh.

Local telcos may have been responsive because of the competition. A news story in the August 1923 issue of Radio News reported, for example, that broadcasts by famed star Bertha Brainerd were sent from her New York theater *via Western Union facilities* to WJZ/WJY. (WJY was a short-lived VLF station set up to compete with WJZ, then being built by Westinghouse)

Unfortunately, Western Union's plant was encumbered by its design; it was built for telegraphy, not wide-band audio. Line imbalance created hum and noise, and audio bandwidth was too restricted for good broadcast quality. These disabilities eventually eliminated Western Union as a potential player in the broadcast-service arena…though even the Radio Group had to use Western Union long-distance circuits for their own startup network.

A “NEMO Service” included the provisioning of one or more ‘Program’ lines, as well as an ‘Order Wire’ circuit provided for station telegraphic communications.   To cue the remote site, Master Control sent the famous “K” (“go-ahead”) to the remote engineer. Sometimes a “ring-down” or “Common-Battery-Signaling” phone line was added to the path. (Not to get ahead of our story but, once the big networks began doing a lot of remotes, “NEMO Preview booths” (separate control rooms with good monitors) were assigned to audition, set and monitor levels and to oversee the remote mixes in a “broadcast quality” listening environment.)

In AT&T’s view broadcasters’ reliance on the local Bell companies was getting out of hand. It was one thing for local RBOCs to be cooperative, but their provisioning had to reflect company policy. A spotlight in Pittsburgh illuminated the issue: Shortly after KDKA took to the air the following request was sent to AT&T engineers: “We require the connection of a transmitter and speech amplifier connected to a telephone circuit. At the station's end we require connection from the telephone wire to the input circuit of a second speech amplifier or to the input circuit of our radio transmitter. We have found it desirable to connect *around* the distributing frame at telephone centrals rather than to go through the switchboard equipment…

“The telephone company will want to know what current and voltage will be applied to their standard telephone circuits…We should be able to get along in all cases without exceeding 100 volts on the telephone circuit. The current should not exceed 100 milliamps. If the above figures are greater than the telephone company is willing to allow we wish to amplify up to what is allowable at the pick-up and finish the amplification at the station. For your information (we) would say that we have had no trouble with this voltage and current while using the telephone circuit of the Independent Company in Pittsburgh.” *Bell Telephone Company files Oct, 1921.*

The Pittsburgh phone guys went to work…but the memo was also sent upstairs. AT&T approved the request but made it clear to KDKA that under its licensing authority this response was not de rigeur. It intended to *‘observe further developments with respect to the company’s public-service obligations*.’ (Internally, the question was: if their obligations *didn’t* mandate universal service, was AT&T undermining its own position by providing ad-hoc service?)

This core question could be put another way: Was AT&T required to provide connectivity to *everyone*…or could it apply strict access rules to protect its network? (“Strict access” might be construed as picking and choosing customers…a practice that got the company into trouble.)

AT&T’s Walter Gifford looked back more than twenty years later: "Nobody knew…where radio was really headed. Everything about broadcasting was uncertain. For my own part I expected that since it was a form of telephony…we were sure to be involved in broadcasting somehow. Our first vague idea, as broadcasting appeared, was that perhaps people would expect to be able to pick up a telephone and call some radio station, so that they could give radio talks. It was impossible for a while even to guess what our service duty would be." *Telephone-The First Hundred Years, John Brooks; Harper, Row, 1975.*

The definition of "service duty" remained flexible; AT&T was still hedging its bets. An inter-office memo on the subject concluded: "Radio-telephone broadcasting bids fair to become such an important matter in the communication world as to warrant a careful consideration of its possibilities from a business standpoint and a redetermination of what interest we may have in the field…the only feasible way of obtaining returns is considered to be through the sale of apparatus. This has led to the conclusion, inasmuch as this company is not interested in the sale of apparatus *outside the Bell System*, that we are not interested in broadcasting." *Commercial Broadcast Pioneer: The WEAF Experiment 1922-1926; Banning* (italics added)

In lawyerly style, the memo, circa 1921, continues: "The exploitation of apparatus sales will be dependent, however, upon some news and amusement broadcasting service; and it would be well worth while for companies interested in the field to underwrite such service in one way or another…it seems reasonable to expect that we will be called upon for wire connections to these broadcasting stations...If we, ourselves, do not broadcast, we have to face such policy complications as the wire end of the service may involve, as well as the uncertainty of what effect such service may have upon our own service. The fact that radio *supplements* wire service could in no way better be demonstrated continually to the public than by having this broadcasting conducted as a part of the Bell System. Certainly we are well prepared in both radio technique and in field setting to undertake it." *ibid*

The engineers added this think-piece to the dialogue: "The technical possibilities of broadcasting from the Bell standpoint may be best indicated by picturing the setup for some national event…we can imagine the President or other official speaking in Washington with or without the use of local loud speakers, and that his voice is then carried out over a network of wires extending to all the important centers of the country. If each point on this network can be reached by two or more routes, the possibility of interruption to telephone service would be small. At the offices along the selected route connections are established through one-way repeaters to other circuits, to loud speakers and radio stations, without interfering at all with the main circuit. In each city and larger town there are halls equipped with loud speaking apparatus at which the people in the neighborhood are gathered and which are properly connected directly or indirectly to the backbone routes. To properly do the above will require that we have available along all of our important routes one or more circuits which are constructed and maintained so as to give a somewhat better grade of transmission, and a…higher degree of reliability." *ibid*

This language spoke to the concern for quality. The fidelity requirements of radio meant the quality bar had to be lifted and held high.

The public-address interfacing with phone lines was the easy part. Getting good audio out to the remote PA point was a bit harder, given the state of the network of the time. Engineers did their best at that and, if AT&T were to formally participate in broadcasting, they would insist on applying the same quality standards to that service.

A final argument for getting into radio was that AT&T believed *only AT&T-licensed* stations had the right to engage in "Toll Broadcasting;" a privilege granted them under the patent pool Licensing Agreement. AT&T should therefore exercise that exclusivity or lose it. (After all their Western Electric division was already in the game in full uniform, designing and selling transmission equipment.)

Having heard all the arguments and now fully understanding the opportunity, executives were ready to make the move. AT&T would commit to an <u>experiment</u> to determine whether "Toll Broadcasting" was feasible and, more importantly, whether it met the company's operating culture and responsibilities.

CHAPTER FOUR

Before we follow AT&T into Broadcasting, we take a moment to recognize its World-Class research arm.

Bell Laboratories

Western Electric brought its Boston and Chicago research offices to New York in 1907. In 1911 AT&T spun off its "last-mile" operating companies into the Regional Bell Operating Companies (those "RBOCs" familiar to most of us). Western Electric's research labs were given the added task of supporting the RBOCs.

The labs grew quickly in response to an infinity of challenges. In 1918 an International Division was created. In 1925 the company split off the manufacturing arm and created **Graybar Electric** (named for Elisha **Gray** and Enos **Bar**ton). That same year the Western Electric Engineering Department became **Bell Laboratories** and began its storied career, sharpening the cutting edge in all forms of technology.

The Bell Labs story has been well told. One of its earliest challenges was motion-picture sound. Then, television by wire between Washington and New York…while also implementing Trans-Atlantic telephone service and service to Mexico…while developing dial-up "TWX" (teletypewriter exchange) service…while working on new designs for undersea cables. What a great time to have been working there!

AT&T Enters the Radio Business

Clearly, AT&T got into radio broadcasting to hedge its bets. There appeared to be an undefined revenue forest; the question was: which trees to tap? Since there were no other facilities available to deliver "Toll Broadcasting" services, AT&T would undertake to provide them (after all they believed this was their exclusive domain under the Licensing Agreement). A Toll Broadcasting Department developed a paper operating organization to see if broadcasting had the potential to mesh with the rest of the company's activities. The decision was finally made to "test toll broadcasting service…through the experience of the American people."

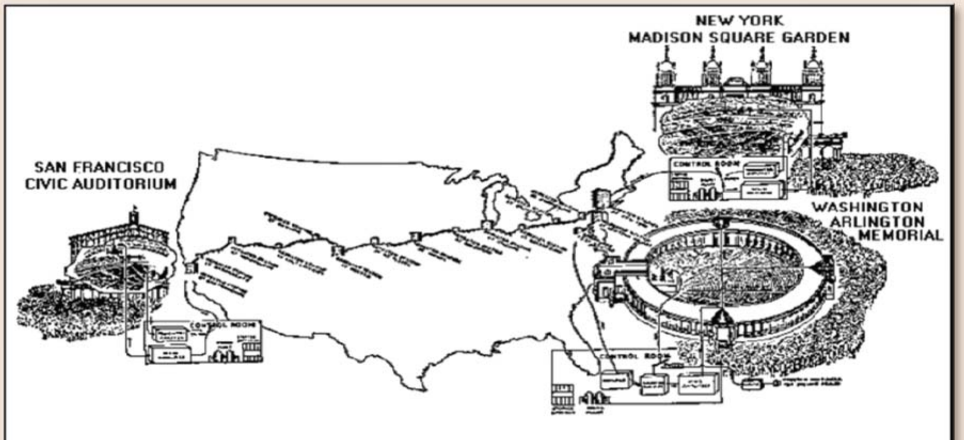
AT&T President Gifford announced the decision in 1921: "A field in which the radio telephone has possibilities is in the furnishing of broadcasting service, a one-way service which consists in sending out by radio telephone from a central station, news, music, speeches, and the like, which under favorable atmospheric conditions may be received by all who have receiving stations within the area served, and care to listen. The number of wave-lengths available for this radio telephone service is limited, but we are preparing to furnish this broadcasting service to such an extent as may meet the commercial demands of the public, subject to that limitation."
Commercial Broadcast Pioneer: The WEAF Experiment 1922-1926; Banning

Gifford went on to suggest that this was the beginning of a *national* vision of 38 or more connected radio stations. "This service would enable advertisers, industrial institutions of all kinds, and even individuals if they desire, to send forth information and advertising matter audibly to thousands. A first consideration is that the material broadcasted (sic) be desirable to the receiver so that the demand for service will be stimulated. Our present plans do not contemplate our providing talent for entertainment ....we propose (instead) to be responsible for the quality of the service in so far as the *broadcasting* is concerned." *ibid* (italics and underlining added)

Networking "Firsts"

It's worthy to note that Long Lines was already making its bones with a number of long-distance radio-transmission milestones. Each of these communications "firsts" was heralded in the public eye as "the next great advancement." Each required an incredible amount of behind-the-scenes effort. In addition to the nascent WEAF Toll Network, Long Lines milestones included:

> Armistice Day, 1921: A "telephonic-grade" hookup stretched across the country from the Tomb of the Unknown Soldier in Arlington, VA to crowds gathered in large cities where AT&T interfaced phone lines with Public-Address systems. An observer noted: "The whole atmosphere was devotional, as of a nation at prayer. At times a wave of quiet weeping swept the place. The thought that gripped the imagination of the dullest mind was that tens of thousands at either edge of the continent were uniting with similar thousands at Arlington and honoring in unison the Unknown Warrior. From San Francisco, 3,000 miles away, came …reports that the voice of the President… reached those in the audience so distinctly that they held their breath in unconscious expectation that he himself might step forward into plain sight."



Telephone circuits and vacuum-tube amplifiers carried President Harding's Armistice Day address, in 1921, from the Tomb of the Unknown Soldier at Arlington to crowds in Washington, New York, and San Francisco. This contemporary diagram shows the course of the circuits.

Text and diagram: 'Long Lines' December 1921

> January 4, 1923: "*American Telephone and Telegraph (connects) First Station in Boston—Two Plants Send Same Program at One Time During Tryout (By F. N. Hollingsworth, Special Correspondent)* New York—An experiment in Radiophone broadcasting, the first of its kind ever attempted, has resulted successfully—so successfully, in fact, that the world's greatest telephone corporation is about to launch the establishment of a chain of Radio test laboratories and Radio toll stations that will extend from the Atlantic to the Pacific coasts, both north and south in two lines. This experiment, preparations for which covered several months, was that of simultaneously broadcasting from a New York station on a 400-meter wave-length and from a Boston station on a 360-meter wave length. The results are declared by experts to have been flawless." *Commercial Broadcast Pioneer: The WEAF Experiment 1922-1926; Banning*

This WEAF-WNAC broadcast was a one-time, one-way shot. The circuit was 300 miles (mixed cable and open-wire), requiring repeaters and conditioning. Of interest is the way AT&T set up these broadcast with a 'belt-and-suspenders' mindset: "From a technical standpoint, the control of a broadcasting station 300 miles from New York by means of telephone lines is a most delicate problem. Four circuits were used to stage this feat. The first was the 'regular' circuit, which carried the program. The second was an 'emergency' circuit, which could be plugged in should the regular one fail through storm or other interference. The third was a 'local' circuit, used in Boston…The fourth was the 'order' circuit, by which the telephone and radio engineers in New York and Boston kept in touch with each other and noted progress of the experiment.

"There were fifteen experts handling the matter at the Boston end. Owing to the care exercised in adjusting the filters and repeaters, there was no distortion; every note coming over as clear as the original. At least a hundred thousand Radiophans (sic), throughout New England and along the Atlantic seaboard, listened in on this remarkable program. Station WNAC has records of being heard as far south as Porto Rico (sic), and Commerce, Texas, as far east as the Azores, and as far west as Montana. Therefore one can imagine the possibilities of this combined broadcasting. The expense of the test was $25,000, but telephone officials say it would have been well worth double that to get the results they obtained." *ibid*

(The new AT&T station WCAP in Washington may have been part of this experiment.)

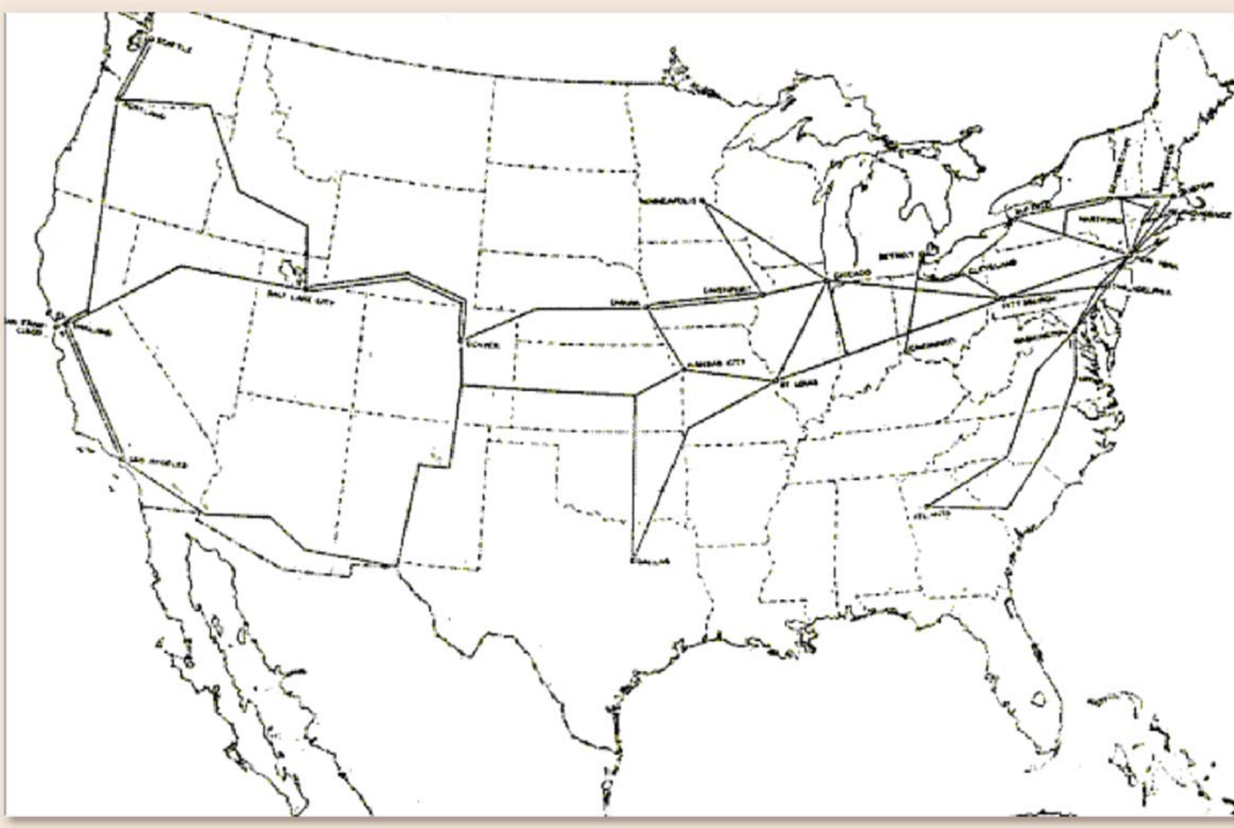
> June 7, 1923: (One-time broadcast) This was considered the first "Chain Broadcast," fed from Carnegie Hall in New York to WEAF, KDKA Pittsburgh, KYW Chicago and WGY Schenectady. Reaction was outstanding.

> June 21, 1923: First live broadcast of President Harding, from St Louis to WEAF New York. It was also aired live by KSD St. Louis (the first station to operate on the new 400 meter wave-length). Harding's folks were so excited they immediately scheduled another broadcast for July 31st, connecting a planned podium in San Francisco with local KPO, WOAW Omaha, WMAQ Chicago, WMAF Round Hill Massachusetts, WEAF New York and WCAP Washington. AT&T engineers scrambled in preparation; Harding died before the broadcast.

> December 6, 1923: New President Calvin Coolidge sent a message to Congress… and to radio listeners around the country. Coverage was a cooperative venture among the three newly-minted stations of the WEAF Network and Southwestern Bell Telephone Company, which added KSD St Louis, WDAF Kansas City and WFAA Dallas.

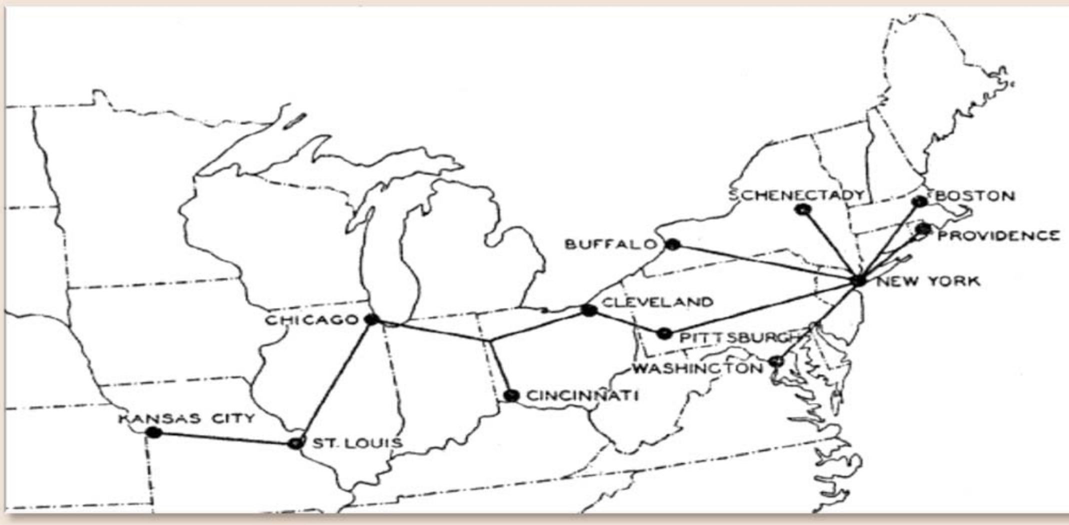
> September 12, 1924: The U.S. Army conducted the first of two “National Defense Day” broadcasts, using AT&T Long Lines to connect 18 stations from coast-to-coast. A recording of that broadcast has survived; the emcee is heard calling the roll of stations and talking with repeater personnel. It was a two-way network; an enormous undertaking. 39,000 miles of telephony-grade and 11,000 miles of telegraph lines were used. Here’s an edited recording of that broadcast, including the station roll-call. http://durenberger.com/natldefday.mp3

The Army was ecstatic and immediately ordered another national hookup for July 1925. AT&T swallowed its objections in patriotic fervor (and because it was good public relations). The 1925 National Defense Day broadcast reached 28 stations, using some 70,000 miles of circuits and an enormous amount of engineering time. Not incidentally, AT&T took the occasion of these major broadcast requests to invest in upgrades that served the network in the long-term. (Presumably they wrote off the upgrades on their books as the cost of performing this ‘Public Service.’)



Second National Defense Day hookup July 4, 1925   *Bell Telephone Record 1934*

> The 1924 Presidential Elections were the first to be broadcast by a network…from the party conventions to 12 stations. This 12-station limit was imposed by AT&T due to a lack of facilities and trained operations personnel. (They did however insist that the 3 AT&T stations on the air at the time be included among the 12.)



1924 conventions network *Bell Telephone Record*

> President Coolidge was the guest speaker at the convention of the United States Chamber of Commerce on October 23 1924. A network of 22 stations broadcast the occasion.

> On Election Eve 1924, 27 stations broadcast Coolidge's final campaign address, with Denver, Seattle, Portland, Los Angeles, Oakland, and San Francisco added to the line (via telephone circuits). "If America's radio listeners hailed nationwide broadcasting as a wonderful experience, the Long Lines men best knew what made it so." *Commercial Broadcast Pioneer: The WEAF Experiment 1922-1926; Banning*

> Coolidge was part of yet another "First." His inauguration to a full term took place on March 4, 1925. A nation-wide hookup of radio stations was augmented by installations of public-address systems connected to the network in areas that did not have local radio.

> "The largest number of radio stations ever connected (to date) was during the Radio Industries Banquet held in New York on September 21, 1927, when a total of 85 radio stations broadcast the proceedings. All…of the regular networks were used and 13 additional points were added." *AT&T: "How chain broadcasting is accomplished" June 1928*

These "firsts" were living lessons for AT&T personnel. Meticulous performance records were kept on these 'sustaining innovations' and each experience made the next a bit better. By the time WEAF called for service for its own "Toll Network," Long Lines was ready to deliver.

Authorized Wavelengths

In a governance model still true today, the limited regulatory power of the Department of Commerce relied on consent of the governed. Herbert Hoover, in search of sanity, called several "Radio Conferences" in the mid-1920's. The broadcasters at these conferences agreed that new wavelengths were needed. Originally all stations had been assigned to the 360-meter wavelength (government and "weather stations" were put on 485 meters). In 1922 the 400-meter band was opened for "high-power" broadcasting (500 to 1000 watts); then the band 300 to 545 meters opened for yet higher-powered stations. The medium-power stations (up to 500 watts) would go to 220-300 meters and the low-power "locals" would stay on 360 meters.

WBAY--the First AT&T Station

In February 1922 AT&T's President Gifford announced the establishment of WBAY, New York City: "It is expected that the work will be started at once and that the station will be ready to begin operations in less than two months' time. This wireless broadcasting station will be unique in many respects. This important radio distributing station is to be equipped with the latest developments of the Bell System, including the use of electrical filters and new methods, whereby, as the business grows…<u>several wave-lengths can be sent out simultaneously from the same point, so that…receiving stations may listen at will to any one of the several services.</u> It will be unique in another respect, because it will be the first radio station for telephone broadcasting which will provide a means of distribution and will handle the distribution of news, music or other program on a commercial basis for such people as contract for this service.

"The American Telephone and Telegraph Company will provide no program of its own, but provide the channels through which anyone with whom it makes a contract can send out their own programs. <u>Just as the company leases its long distance wire facilities for the use of newspapers, banks and other concerns, so it will lease its radio telephone facilities and will not provide the matter which is sent out from this station.</u>" *Commercial Broadcast Pioneer: The WEAF Experiment 1922-1926; Banning* (underlining added)

"Science and Invention" shaped the announcement in flowery language: "This wireless broadcasting station will be unique in many respects…The company will provide channels thru which anyone with whom it makes a contract can send out his own programs, just as the company leases its long distance telephone wire facilities…if there appears a real field for such service, and it can be furnished sufficiently free from interference from other radio services, it will be followed as circumstances warrant by similar service from stations erected at important centers thruout (sic) the United States by the American Telephone and Telegraph Company.

"As these additional stations are erected, they can be connected by the toll and long distance wires of the Bell System, so that from any central point the same news, music or other program can be sent out simultaneously…by wire and wireless with the greatest possible economy and without interference." *Science & Invention, April, 1922, courtesy Thomas H White*

In 1923 A. H. Griswold, assistant vice-president in charge of radio matters, said to a Bell System radio conference, "We have been very careful, up to the present time, not to state to the public in any way...the idea that the Bell System desires to monopolize broadcasting, but the fact remains that it's a *telephone* job, that we are the *telephone people*, and that we can do it *better* than anyone else...in one form or another, we have *got* to do the job." Griswold went on to assure his listeners that his view was shared by the company's top officers. *Telephone-The First Hundred Years, John Brooks; Harper, Row, 1975* (italics added)

The Long Lines Division assumed operational responsibility for, and housed the new station at its Walker Street headquarters. Engineers were expected to keep the company positioned as a provider of quality service; a de facto Long Lines principle. Now engineers learned a new craft.

WBAY came up on the ill-fated 360 meters in the summer of 1922. Because of airwave congestion, WBAY had to time-share with others; their total *weekly* time-share allotment was *7 ½ hours!* It was soon discovered that, in addition to the limited hours, the roof-top antenna was sized wrong for 360 meters and oriented wrong for New York City. (AT&T engineers quickly became adept at "Field Strength Measurements" to prove the case.) WBAY was coming up short; especially when compared with competitor WJZ.

WBAY antenna: Long Lines Building on Walker Street, New York *Bell Telephone Record*

WEAF Facilities

Western Electric had meanwhile been quietly testing its own station, WEAF, on the wide-open 400-meter band. WEAF's signal blew away both WBAY and WJZ. It was probably a short conversation at AT&T Headquarters: 'Take over WEAF and switch WBAY's programming to that transmitter.' A few weeks later it was done. WBAY soon disappeared. WEAF was licensed at 500 watts on 400 meters as a "Toll Broadcaster." The station offered air time for sale in long-form blocks. The reaction was underwhelming.

Then someone thought about dividing air-time into smaller segments. The first such segment aired as a "commercial" on WEAF on August 28 1922. The client was the Queensboro Corporation, selling real-estate development. The cost for the first commercial: $50.

This time the response was awesome.

At first, advertising was "institutional"- there was no "selling" but merely courtesy announcements identifying sponsors of programs. Prices could not be mentioned after 5pm, and sponsor mention was to be minimized (they got around this by naming musical groups after the sponsor…so every time the band was mentioned in music programs, the sponsor got his plug).

In 1923 Secretary of Commerce Herbert Hoover said: "It is inconceivable that we should allow so great a possibility for service to be drowned in advertising chatter." No one was paying attention. In fact, for the first year of its existence, WEAF's revenues were disappointing.

In the following years WEAF felt its way through a business becoming daily more competitive. Stories abound of the rivalry between WEAF and WJZ; both stations claiming many legitimate broadcasting "firsts" and both advancing the state of the art.

WEAF of course was only part of AT&T's plan. The meat and potatoes of the "research" project was the national "Toll Network." With a monopoly on long-distance telephony and the resources to develop their network for program-quality service, it might be noted that the network part of AT&T's "Toll Broadcasting" scheme was developed in self-interest…as an escape strategy in case the WEAF experiment crashed.

Queensboro aside, responding to the lukewarm response to advertising efforts, WEAF's people advised the faint-hearted at AT&T to keep the faith and remember the larger picture: "Our experience has shown that there is a real demand for broadcasting for hire…there is also a large potential demand…on the part of *national* advertisers. The best and most economical way to conduct such national broadcasting is to render the program at some convenient city, such as New York, and to simultaneously distribute the program by wire to broadcasting stations in a number of different cities." *Commercial Broadcast Pioneer: The WEAF Experiment 1922-1926*

The initial goal for the WEAF Toll Network was 16 to 20 stations along the route of the wire network. Quality was always the AT&T watchword, so target candidates were selected for their coverage, stability, signal and market penetration. (Perhaps not coincidentally, almost all of these stations used Western Electric equipment.) Further definition brought the early target list to 21 including: WTAT Boston, WJAR Providence, WGR Buffalo, WFI Philadelphia, WDAR and WCAP Washington, WCAE Pittsburgh, WJAX and WTAM Cleveland, WCX and WWJ Detroit, WLW and WSAI Cincinnati, WGN Chicago, WOC Davenport, KSD St. Louis, WLAG(WCCO) Minneapolis, WHB and WDAF Kansas City and WFAA/WBAP Dallas. Most if not all these stations qualified for operation in the 400-meter band. Thus did AT&T hope to monetize its "Exclusive License" to use the airwaves for hire.

Toll Network 'Candidates' Reaction

Not all the targets were excited about the idea of a commercial network. Many believed that broadcasting was meant for "good will," and felt that commercials, even if indirect, were a violation of the trust assumed by the grant of their licenses. Despite their initial objections, the unwashed were led to the bath. WCCO Minneapolis, WOC Davenport, WWJ Detroit, WSAI & WLW Cincinnati, WEAR Buffalo and WOO Philadelphia agreed to join the proposed group.

Growing the WEAF Network

Affiliates in hand on paper, the next step was to establish the station connectivity. Following the WEAF-WNAC Boston test, longer-form programming was tried in July 1923 between WEAF and WMAF in Round Hill Massachusetts (this was a short-lived deal between radio pals). To make it happen, engineers had to tame a mix of open-wire and cable. AT&T records show: "Service to Station WMAF from (WEAF) 195 Broadway studio started July 1st, 1923; hours, 4:30-5:30 P.M., 7:30-10 P.M., daily except Sunday; Sunday, 7:20-10 P.M. Transmission nominally from 100 to 5,000 cycles but down 10 db at 5,000 cycles. Final equalization accomplished by resonant shunt at 2,000 cycles, giving a 1,000 cycle loss of 12 db. Resulting transmission within 3 db between 200 and 3,500 cycles, down 10 at 5,000 cycles, down 8 at 100 cycles." *ibid* (Doesn't seem like a very "flat" circuit, does it?)

The WMAF arrangement was a 'summer-only' deal. For AT&T to test the concept of Chain Broadcasting, at least one other *full-time* station was needed. It was WJAR, Providence, Rhode Island. From the technical records: "Service to WJAR starts Sunday, October 14th (1923); repeat on Fridays and Sundays until further notice; requires transmission frequencies up to 5,000 cycles.…in the meantime Outlet Company wants to broadcast World's Series baseball which starts October 10th. Transmission of this will require equalization only up to 3,000 cycles but it seems desirable to equalize up to 5,000 at the start." *Commercial Broadcast Pioneer: The WEAF Experiment 1922-1926*

WCAP in Washington had come on the air in April, 1923. The call letters were said to stand for the "**C**hesapeake **A**nd **P**otomac" Telephone Company. Beyond connectivity with WEAF, this station built its own solid reputation in Washington and was instrumental in many AT&T network and propagation tests. It began life sharing time with WRC and, in 1926 with the formation of NBC, quietly disappeared in favor of WRC.

The Colors Do Mean Something

In 1923 WEAF-WJAR-WCAP formed the first full-time radio network ("The WEAF Network"). WEEI, WGR and WCAE were soon added. These six stations now became the "Expanded WEAF Network." This is where the fabled network-coloring scheme began, for AT&T Long Lines engineers did indeed use a red pencil to describe the network routing on their route maps.

The Long Lines engineers were now reminded that AT&T had plans for hookup of more stations in more cities. Engineers pushed back, reminding their bosses that such full-time connectivity might seriously affect the network's ability to handle its core business: peak telephone traffic. Another internal memo resulted: "Every individual broadcasting undertaking was a special problem to the long-distance operating unit, *for its facilities has been designed and built for telephone purposes only.* The conception of a network for regular service was thus a separate challenge to provide the necessary circuits *without impairing the organization's ability to meet the public need for long-distance service*. *ibid* (italics added)

The primary consideration in estimating wire costs for a network was, therefore, circuit availability. This concern can be noted in a September, 1923 warning by the Long Lines Director who thought there might be occasions involving the question of "…priority in use of Long Lines circuits as an adjunct to radio broadcasting. Last night…we had a specific case, in which the circuits normally used for connection between WEAF and WCAP in Washington were unavailable on account of induction…in this specific case, an available circuit as an emergency proposition meant cutting into the New York-Havana circuit group." *ibid*

Traffic Issues

The continued concern was whether the long-haul network was capable of providing the additional audio bandwidth to meet the demand for expanding national radio-program distribution needs without affecting AT&T's core long-distance business.

The execs were still listening to the engineers but the engineers for their part must have seen the handwriting on (the colored map). The build-out was done slowly, deliberately, and with AT&T quality and reliability as design drivers. Here for example is an internal communication regarding a 1924 broadcast. It's lengthy and detailed, but if you want to drill down into traffic assignment, the memo supplies a feel for the precision of Long Lines Engineering:

Long Lines Engineering Memo: "January 31, 1924. This telegram concerns the Long Lines service in connection with broadcasting the AIEE program on February 5th, from the Philadelphia Metropolitan Opera House; Gimbel Brothers Station (WIP), Philadelphia; Station WEAF, New York; Station WGY, Schenectady; Station WCAP, Washington; Station KDKA, Pittsburgh; per SCS Order G-7606. "For this service these telephone facilities will be required: Pairs 257 and 260 Cable C, Philadelphia to New York, with 4-Wire repeaters at Philadelphia, Princeton and New York. No. 2 Chicago-New York circuit between New York and Pittsburgh. No. 2 Boston-Pittsburgh circuit between Newtown Square and Pittsburgh. No. 3 Harrisburg-Philadelphia. circuit between Newtown Square and Philadelphia. Nos. 7 and 25 New York-Washington circuits…New York and Washington. Sides of 33-36 group, New York-Buffalo, New York to Lansingburg. Sides of 27-30 group, Troy-Elmira line, Lansingburg to Schenectady.

"For this service the following Morse facilities will be required: 0194 program co-ordinating circuits with Morse calls and drops as follows: New York (BY) radio station WEAF Philadelphia (KF) control room Philadelphia (RF) radio station WIP (not to be connected unless asked for later) Pittsburgh (RW) radio station KDKA Washington (CA) radio station WCAP Schenectady (GY) radio station WGY; the above circuit to be operated metallic Morse New York, Philadelphia, Harrisburg, Bedford, and Pittsburgh; leg Philadelphia to Washington and New York to Lansingburg half duplex. Single, Lansingburg to Schenectady.

"0764 telephone repeater test wire calls as follows: New York (NR), Princeton (PN), Philadelphia (PA), Philadelphia control room in Opera House (KF), Newtown Square (NS), Harrisburg (HE), Brushton (GX), Washington testroom (W), Lansingburg testroom (R). This circuit to be operated half duplex upset New York and Philadelphia with Princeton in series on regular day assignment of 764 or similar facilities, any available facilities half duplex or metallic Morse Philadelphia to Washington and leg Philadelphia to Pittsburgh via Harrisburg, loop Newtown Square in from Philadelphia. Leg Lansingburg on from New York half duplex.

"These telephone and Morse circuits shall be established for rehearsals on Sunday, February 3rd, 8:00 P.M.--11:00 P.M., E.T., and again on Monday, February 4th, 5 P.M.--9 P.M. E.T. On Tuesday, February 5th, the night of the demonstration, the circuits will be taken at 5:00 P.M., E.T., lined up and held until 'good night.' During the periods of rehearsals and demonstration, telephone repeater attendants required at repeater stations en route, and transmission man required at New York, Pittsburgh and Philadelphia. For this service provide a New York-Philadelphia order wire between Room 224, 24 Walker Street, N.Y., and the telephone repeater room at Philadelphia and control room of Philadelphia Opera House on dates of rehearsals and demonstration. For this purpose use any New York-Philadelphia circuit. Should these facilities be required…during any other period than after 7:30PM, further consideration should be given with regard to their release. (RSS)" *ibid*

Fortunately, much of the system was still open-wire facility; open-wire made the job a lot easier because of its inherently-wider bandwidth and lower losses.

As we saw above, until dedicated "wide-band" facilities were commonly available, engineers had to take telephone circuits out of service, disconnect them from their switchboards, add conditioning and test them. This work had to be accomplished during periods of low telephone demand. Sometimes, after testing for several hours, the pairs chosen delivered too much noise or cross-talk…and the work had to be re-started on different pairs…in the middle of the night.

AT&T Toll Network Program-service Design

Within the organization, the feasibility of connecting the first few stations drew the following internal correspondence: "At the present time the circuits between New York and Providence and New York and Washington used for broadcasting purposes are non-loaded 165 (mm open-wire) circuits with a small amount of intermediate cable. The circuit to Providence is equipped with two intermediate amplifiers and equalizers…Extra-light-loaded H-44-25 #19 gauge cable conductors which are used for extra-light loaded four-wire circuits, if equipped with suitable repeaters or amplifiers, can be made to transmit the average program from WEAF with about the same degree of satisfaction to the listener as the present circuits…

"New York to Philadelphia: There are at present 6 quads of H-44-25 $19 gauge four-wire conductors between New York and Philadelphia. One of these quads could be released for use in broadcasting. Philadelphia to Washington. There are at present no extra-light loaded conductors between Philadelphia and Washington and it would be necessary to load existing spare #19 gauge non-loaded conductors in this section. New York to Providence: There is no H-44-25 loading between New York and Providence. There is, however, one spare non-loaded quad from New York to Providence which could be loaded and used for broadcasting. "A special amplifier or repeater…would be required at each of the repeater points along both of the cable routes.

"Summary: The cable distance between New York and Washington is 223 miles, and the distance between New York and Providence is 187 miles. The total distance over which additional loading would be required is 323 miles, since the 87-mile section between New York and Philadelphia is already loaded." *ibid*

Attached to the memo was the usual cost projection helping AT&T determine the financial risks.

Network *Modifications* for Program Transmission

The circuits used for the WEAF Network were part of the telephone network that had been engineered for the transmission of speech only. 135 cps Composite ringing was normally used between switchboards as we noted earlier, so the repeat coils in use were for lower voice-band loss…at the expense of low-frequency response. For broadcast transmission these efficient and lossless voice-quality repeat coils had to be replaced with full-range transformers. Equalizers and repeaters had to be readjusted for the wider bandwidth. It was not unusual for hundreds of man-hours to be expended for a single one-hour broadcast.

"Broadcast" Channel configuration

As previously noted, a typical long-haul broadcast service used a minimum of three channels: a Primary, an Emergency and an Order-Wire (telephone-grade) circuit for communications. Occasionally a fourth "monitor" circuit was used for listening to the off-air signal, so the transmission tech could flip the Primary to the Emergency circuit if he heard problems. Since phantom groups were in wide use on open-wire plant, the special hazard of cross-talk had to be monitored. Cross-talk could occur from the broadcast circuits TO the phantom being used for telephony…usually tolerable. *But cross-talk from the phantom to the program circuits could cause a private telephone conversation to find its way to a broadcast transmitter.* Bad idea!

Given the number of repeaters and other gain blocks in these circuits it was also possible that cross-talk could be induced by abnormal tandem gain settings. It was all a careful, coordinated dance. Long Lines engineers and operators became very proficient at following the orchestra.

The Business Side: Network Rivalry

Now there was competition of a sort. Thomas White reports: "Although the proposed umbrella broadcasting company was not organized at this time, the Radio Group members (GE, Westinghouse, RCA) did increase cooperative efforts. The original plan was for the Group's stations, starting with…WJZ in New York, to expand coverage by increasing transmitter outputs to "superpower" status of 50,000 watts…although the higher powers did help improve regional coverage, even 50,000 watts wasn't powerful enough to achieve the goal of covering the entire nation with signals…one way to economize was to emulate AT&T by connecting the stations together to simulcast programs. WJZ would be the key station; WBZ, WGY and WRC and perhaps a Pittsburgh and Chicago station were expected to be on the line at various times. But transmission quality suffered from the use of Western Union's telegraph lines. These wires worked reasonably well for shorter distances…for example, telegraph lines were used on October 7, 1922 to haul the World Series to WJZ's transmitter in Newark, New Jersey.

"The Radio Group soon found that telegraph companies didn't have staffs of acoustics experts or a history of installing lines with more fidelity than that needed for the less demanding requirements of a telegraph service, so for longer distances, the telegraph circuits just wouldn't work. Poor sound quality was sometimes accompanied by annoying hums." *Thomas H. White* *http://earlyradiohistory.us/index.html*

AT&T Acting Out a *Broadcast* Monopoly?

GE, RCA and Westinghouse wanted to develop their own network but AT&T wouldn't offer service. Litigation was threatened, with government intervention to be called up if necessary. The issue that attracted the government's eyes in 1925 was whether AT&T had gone too far in denying competitors access to its network. AT&T of course construed the original Licensing Agreement as conferring sole rights to "Toll Broadcasting" to itself and its associated stations.

"Up to early 1922, it was AT&T's policy to refuse the use of Bell telephone wires…to radio stations not owned by Bell. There was a relaxation of this hard-line policy in April, 1922, when AT&T informed its operating companies that it now seemed desirable…to be liberal in the matter of leasing *private* lines to broadcasters. However, the stations owned by AT&T's chief competitors in broadcasting—Radio Corporation, General Electric and Westinghouse—were specifically excluded from the new…policy, under AT&T's interpretation of the 1920 agreement. Those stations were forced to resort to the use of telegraph wires."
Telephone-The First Hundred Years, John Brooks; Harper, Row, 1975.

AT&T also thought its license for Toll broadcasting meant that even those stations licensed by AT&T had to pay *an additional license fee to go commercial* (shades of iBiquity).

All of this finally brought in Congress…and that brought in the Federal Trade Commission.

The 1925 Negotiations

The FTC opened the 1920 Cross-Licensing Agreement. But management on both sides wanted the government to stay out of the way; it seemed prīmā faciē that AT&T and The Radio Group had agendas that might both be satisfied by reasonable internal discussion. These issues:

> The Radio Group thought the 1920 Licensing Agreement included access to AT&T's lines.

> AT&T wanted the right to manufacture tubes for its own business (usage estimated between 1 and 2 million tubes in the Bell System).

> AT&T wanted to build radios.

> The Radio Group wanted to get its hands on WEAF. Their position: the station could be better utilized 'in the public interest' than had been demonstrated by AT&T's operation.

The threat of government interference was probably not formidable, given its dismal track record in regulating the industry. (Historians will recall that due to a Circuit Court override of Hoover's Commerce Department authority, the "Chaos of 1926" created near-anarchy on the radio dial.) Pundits didn't see the Federal Trade Commission as having the chops or the understanding to referee this fight.

At the end of the day, AT&T's overriding concern was to protect its traditional areas of operations and technical developments…including future sound and film advances and television in which Bell Labs was now playing. The matter went to arbitration; the arbitrator flunked.

So both sides sat down in a smoke-filled room and hammered out a historic agreement. The meetings were intense, difficult, protracted…and short. In a matter of days a five-year conflict was ended to the parties' mutual satisfaction.

Sale of AT&T Broadcast Interests

When the smoke in the room cleared, WEAF was sold to The Radio Group for a million dollars; AT&T agreed to quit broadcasting and to provide universal access to its system (through its own interfaces of course). AT&T also surrendered the right to exact a license fee for commercial broadcasting, even for stations using Western Electric equipment.

In The Radio Group, Long Lines now had a huge customer for its program-transmission business (the 10-year transmission contract was valued at a million dollars per year). Furthermore, Western Electric could now manufacture tubes and AT&T could manufacture radio sets for its own purposes (though it rarely exercised this privilege). Over the following years Western Electric would remain a strong force in building station equipment and sharing the leadership in tube manufacturing.

Not a bad place to end up.

Gifford explained in the annual report (for 1926): "The Company undertook to develop radio broadcasting in order to ascertain how it could be made most useful in the business…The further the experiment was carried, the more evident it became that the objective of a broadcasting station was quite different from that of a telephone system. (This)…meant that AT&T --under pressure, to be sure --had given up another dream of monopoly, and that entertainment stars would no longer enliven the scene at 195 Broadway."
Commercial Broadcast Pioneer: The WEAF Experiment 1922-1926; Banning

"…the selling of WEAF was the beginning of the end of AT&T's venture in broadcasting *even though it later attempt to set up its own network."* *The Broadcast Century, Hilliard and Keith* (italics added)

(I've been unsuccessful in chasing down this reported 'new-network' move by AT&T; it may have never happened.)

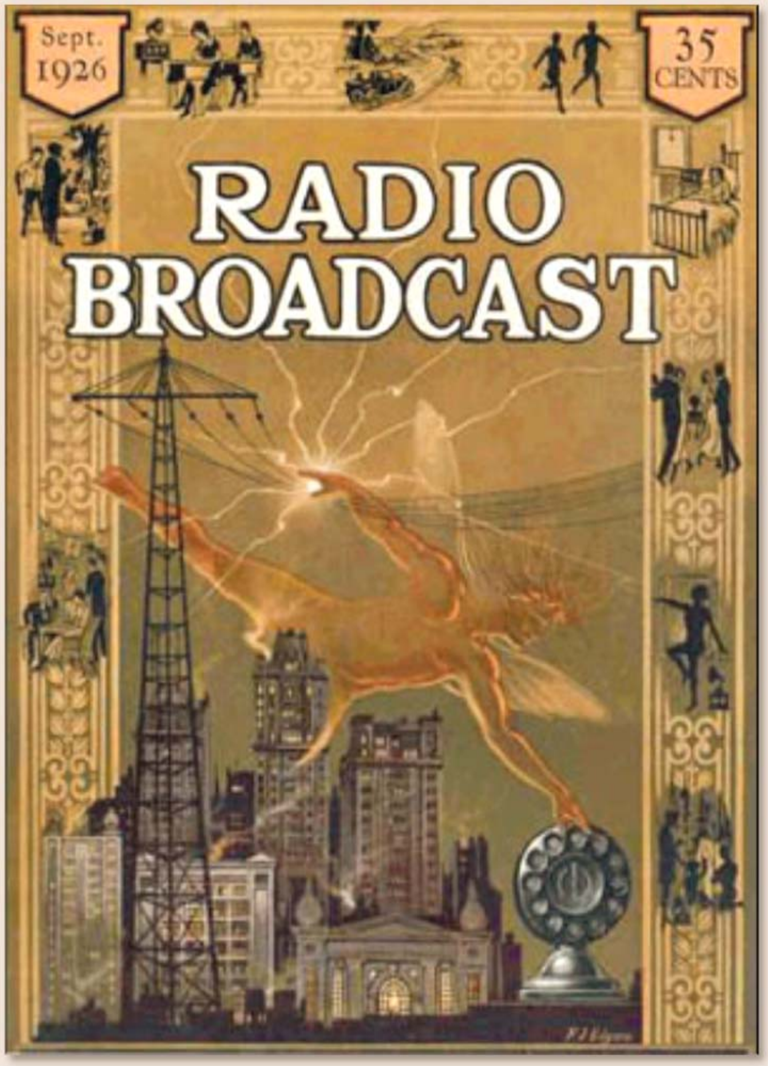
It had been hard work for AT&T in those first few years of "testing" Americans' response to radio broadcasting. Along the way WEAF had come of age. (By the way, the WEAF story never really ended. WEAF is still on the air; several call-letter changes later it's WFAN-660. Ironically, through its commercials, WFAN has been the top-billing sports station in the world.)

Not a lot of stations were as successful. Of the several hundred stations on the air when WEAF came to life, only about two-thirds survived. Some did so by an all-out commitment to local community. Some prospered by sharing a network with other stations. Some folded.

Radio was never an easy business to be in, in spite of its apparent "glamour."

Thus ended the "WEAF Experiment." Thus began large-scale network radio in America.

As if closing the chapter on the original WEAF, *Radio Broadcast* published its iconic cover on the September 1926 issue, as NBC was preparing to light up. That cover memorialized the magic, the power and the progress of the new 'mass medium.'



CHAPTER FIVE

AT&T and the Radio Networks

Across the radio business a solid case had been made for the value of networking stations. When it came to the program-network game, the only team in town was the telephone company…and it owned the football and sold the tickets.

In some early cases, however, the affiliates' goal posts kept moving. In "American Broadcasting," Schlichty and Topping note that: "Network facilities making possible the distribution of programs to all parts of the nation would not have been sufficient to attract sponsors to radio…unless, at the terminals of the network wires, there were transmitting stations capable of putting out a broadcast signal *on a regular basis* with a minimum of interference. Prior to 1926 these conditions did not obtain; the…task at local stations was not the development of programming, but the problem of keeping the station on the air.

"After 1926, station transmitters were fairly dependable, but stations' schedules remained irregular because of the necessity in many cases of sharing wave-lengths. Station WMAQ, Chicago, for instance, interrupted its broadcasting four times each day to give other stations air time, as late as September 1928. In fact, the hours of operation among Chicago stations were such that in order to reach that city with (its) programs…*the Columbia Broadcasting System had to sign affiliation contracts with three stations*, and in order to reach it with two networks, *NBC needed five stations.* Furthermore, all local stations observed a "night of silence" on Mondays to enable Chicago listeners to tune-in distant signals.

"Thus, during the 1927-28 season, the advertiser could not have the broadcasters' assurance of a full, daily, stable program schedule. It was the activity of the Federal Radio Commission in 1927 and 1928 that soon made it possible for broadcasters to give that assurance."
American Broadcasting, Schlichty/ Topping (underlining added)

The situation was exacerbated by the Federal Radio Commission's reassignment follies during this period. Through its General Order Nr 40 and associated rulemakings, some stations were assigned as many as three or four different frequencies during the span of a couple of years. Changing frequency was not always a trivial exercise; antennas sometimes had to be completely rebuilt and sometimes transmitters replaced.

A New Life for WEAF

With the "WEAF Experiment" AT&T had met some of its stated goals: 1) to determine the public's taste for 'commercial radio;' 2) to evaluate the practicality of upgrading the telephone network for program transmission; and 3) to control the market for its core businesses. They probably scored two out of three.

Most of WEAF’s creative staff and support cadre turned in their AT&T I-D cards and moved with WEAF to The Radio Group, continuing to empower a station that in many ways had made an indelible mark on the business. The Radio Group, including the stations of GE and Westinghouse, planned to deploy the WEAF Network under a new name and in November 1926 announced the “National Broadcasting Company.” Of this development, RCA’s Sarnoff was fond of saying: "when life hands you a lemon, make lemonade.” The AT&T settlement altered the dictum to: "when life hands you a lemon…buy the other guy's lemonade stand.”

Announcing the

National Broadcasting Company, Inc.

National radio broadcasting with better programs permanently assured by this important action of the *Radio Corporation of America* in the interest of the listening public

THE RADIO CORPORATION OF AMERICA is the largest distributor of radio receiving sets in the world. It handles the entire output in this field of the Westinghouse and General Electric factories.

It does not say this boastfully. It does not say it with apology. It says it for the purpose of making clear the fact that it is more largely interested, more selfishly interested, if you please, in the best possible broadcasting in the United States than anyone else.

Radio for 26,000,000 Homes

The market for receiving sets in the future will be determined largely by the quantity and quality of the programs broadcast.

We say quantity because they must be diversified enough so that some of them will appeal to all possible listeners.

We say quality because each program must be the best of its kind. If that ideal were to be reached, no home in the United States could afford to be without a radio receiving set.

Today the best available statistics indicate that 5,000,000 homes are equipped, and 21,000,000 homes remain to be supplied.

Radio receiving sets of the best reproductive quality should be made available for all, and we hope to make them cheap enough so that all may buy.

The day has gone by when the radio receiving set is a plaything. It must now be an instrument of service.

WEAF Purchased for $1,000,000

The Radio Corporation of America, therefore, is interested, just as the public is, in having the most adequate programs broadcast. It is interested, as the public is, in having them comprehensive and free from discrimination.

Any use of radio transmission which causes the public to feel that the quality of the programs is not the highest, that the use of radio is not the broadest and best use in the public interest, that it is used for political advantage or selfish power, will be detrimental to the public interest in radio, and therefore to the Radio Corporation of America.

To insure, therefore, the development of this great service, the Radio Corporation of America has purchased for one million dollars station WEAF from the American Telephone and Telegraph Company, that company having decided to retire from the broadcasting business.

The Radio Corporation of America will assume active control of that station on November 15.

National Broadcasting Company Organized

The Radio Corporation of America has decided to incorporate that station, which has achieved such a deservedly high reputation for the quality and character of its programs, under the name of the National Broadcasting Company, Inc.

The Purpose of the New Company

The purpose of that company will be to provide the best program available for broadcasting in the United States.

The National Broadcasting Company will not only broadcast these programs through station WEAF, but it will make them available to other broadcasting stations throughout the country so far as it may be practicable to do so, and they may desire to take them.

It is hoped that arrangements may be made so that every event of national importance may be broadcast widely throughout the United States.

No Monopoly of the Air

The Radio Corporation of America is not in any sense seeking a monopoly of the air. That would be a liability rather than an asset. It is seeking, however, to provide machinery which will insure a national distribution of national programs, and a wider distribution of programs of the highest quality.

If others will engage in this business the Radio Corporation of America will welcome their action, whether it be cooperative or competitive.

If other radio manufacturing companies, competitors of the Radio Corporation of America, wish to use the facilities of the National Broadcasting Company for the purpose of making known to the public their receiving sets, they may do so on the same terms as accorded to other clients.

The necessity of providing adequate broadcasting is apparent. The problem of finding the best means of doing it is yet experimental. The Radio Corporation of America is making this experiment in the interest of the art and the furtherance of the industry.

A Public Advisory Council

In order that the National Broadcasting Company may be advised as to the best type of program, that discrimination may be avoided, that the public may be assured that the broadcasting is being done in the fairest and best way, always allowing for human frailties and human performance, it has created an Advisory Council, composed of twelve members, to be chosen as representative of various shades of public opinion, which will from time to time give it the benefit of their judgment and suggestion. The members of this Council will be announced as soon as their acceptance shall have been obtained.

M. H. Aylesworth to be President

The President of the new National Broadcasting Company will be M. H. Aylesworth, for many years Managing Director of the National Electric Light Association. He will perform the executive and administrative duties of the corporation.

Mr. Aylesworth, while not hitherto identified with the radio industry or broadcasting, has had public experience as Chairman of the Colorado Public Utilities Commission, and, through his work with the association which represents the electrical industry, has a broad understanding of the technical problems which measure the pace of broadcasting.

One of his major responsibilities will be to see that the operations of the National Broadcasting Company reflect enlightened public opinion, which expresses itself so promptly the morning after any error of taste or judgment or departure from fair play.

We have no hesitation in recommending the National Broadcasting Company to the people of the United States.

It will need the help of all listeners. It will make mistakes. If the public will make known its views to the officials of the company from time to time, we are confident that the new broadcasting company will be an instrument of great public service.

RADIO CORPORATION OF AMERICA

At first Sarnoff did not want to continue what WEAF had been doing; his own vision for a network was purportedly far more noble. He had said he wanted to build a non-commercial national group, operating in the public interest (patterning the concept after the BBC). But not long after he acquired WEAF he changed his song…perhaps the million-dollar WEAF price tag and the expectations of the Radio Group's Board helped clarify his vision.

NBC's inaugural broadcast for the WEAF (Red) network took place on November 15, 1926. Sadly, no known recordings of that broadcast exist. In addition to the existing WEAF network the broadcast was made simultaneously on WJZ, WEEI (Boston) WLIT (Philadelphia), WRC (Washington), WDAF (Kansas City), and WWJ (Detroit). There were probably others.

The 'other' network that had been anchored by WJZ over inferior Western Union wires now migrated to AT&T; the "Blue Network" formally opened its microphones on January 1, 1927 with WJZ as the flagship. (The Blue Network also got its name from the AT&T map color; "NBC Red" retained the original color of the WEAF Toll Network.)

The Upstart Columbia

Though there was a lukewarm ongoing talent search at NBC, for the moment at least the entertainment resources inside the WEAF and WJZ staffs 'provided all that listeners should need,' thank you very much. That was fine for New York, but performers of broader appeal were key to attracting a wider audience. Sarnoff took a meeting with an Artists' Rep named Arthur Judson who wanted to provide star-quality performers. Sarnoff suggested Judson form a talent group. Judson was barely out of the building when Sarnoff decided he'd build his own talent pool. He walked away from Judson, using Judson's ideas to form the NBC Artists Bureau.

Judson believed he had a valuable product, so in 1927 he formed a small radio network to make use of his entertainment cadre. It began as "United Independent Broadcasters." United came on the air in 1927 and became an immediate money-sink. While Judson had the artists lined up, the cost of AT&T transmission was killing him. He sought investors; the Columbia Phonograph company agreed to provide stop-gap funding…IF Judson would rename the network "The Columbia Phonograph Broadcasting System." On AT&T maps Columbia became the "Purple Network." Audio began to flow on September 18, 1927. There were 16 stations in the line-up.

Columbia soon tired of the losses and sold out to the Levy brothers in Philadelphia…who brought on board a smooth young fellow named William S. Paley. Paley's family was part owner of the Congress/La Palina Cigar Company. This outfit spun off a lot of cash and was pleased by the reaction to its advertising on Judson's network. The cigar company became a major investor in Columbia. Thus began the storied lifelong competition between Sarnoff and Paley; it was probably good for the American listener since the networks became fierce combatants and sought through the years to outdo each other in broadcasting accomplishments.

Judson? He went back to being an Artists' Rep.

Mutual

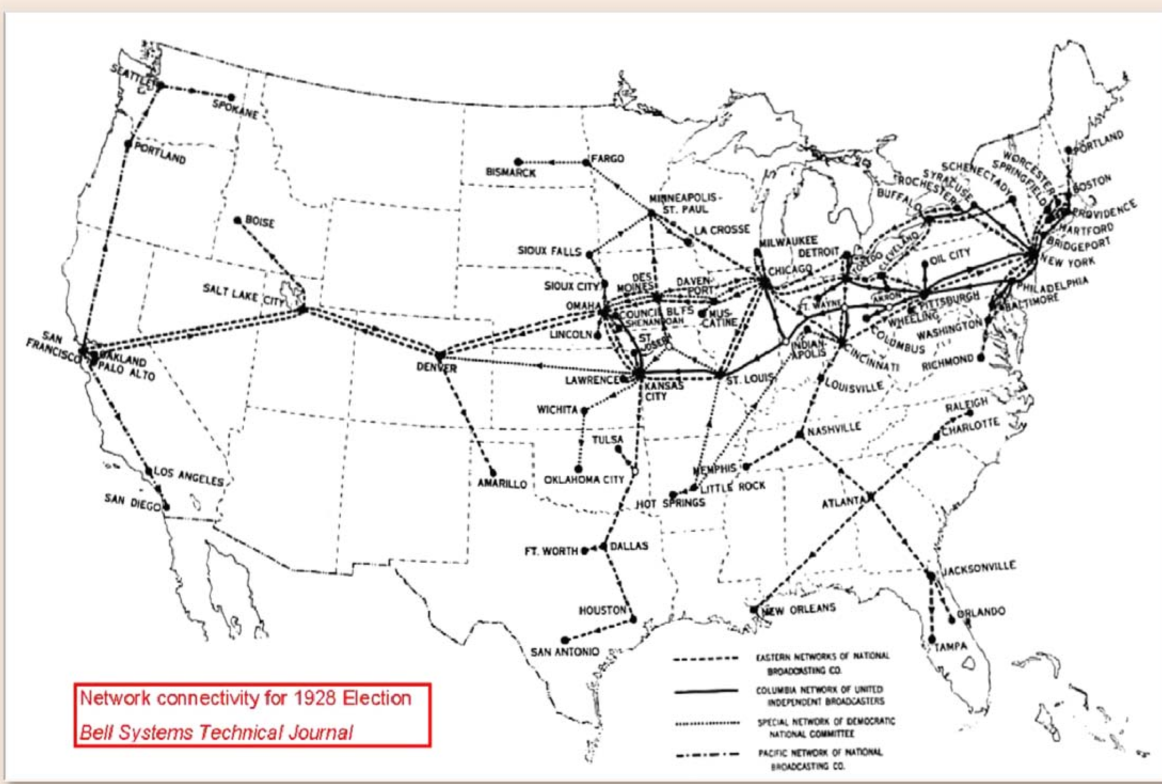
Though this is getting ahead of our timeline, it's a good place to look at the start of the Fourth Network. In 1929 WOR, WLW and WLS created a cooperative called "The Quality Network." The idea was to place air-time buys on a selected group of stations and, soon, to *feed* those stations the sponsored programs.

To clear the hot new "Lone Ranger" radio show, WXYZ Detroit was added. Because the raison d'etre for this group was to function as a cooperative enterprise, the name "Mutual" lent itself nicely to the image.

While the appeal of high-power broadcast stations looked good on a map, Mutual knew that there weren't many high-power signals that weren't affiliated with NBC and CBS. The solution to carrying a big load was to fill the wheelbarrow with smaller rocks. Many lower-power regional and local stations were added and eventually Mutual would become the network with the largest affiliate account.

National News

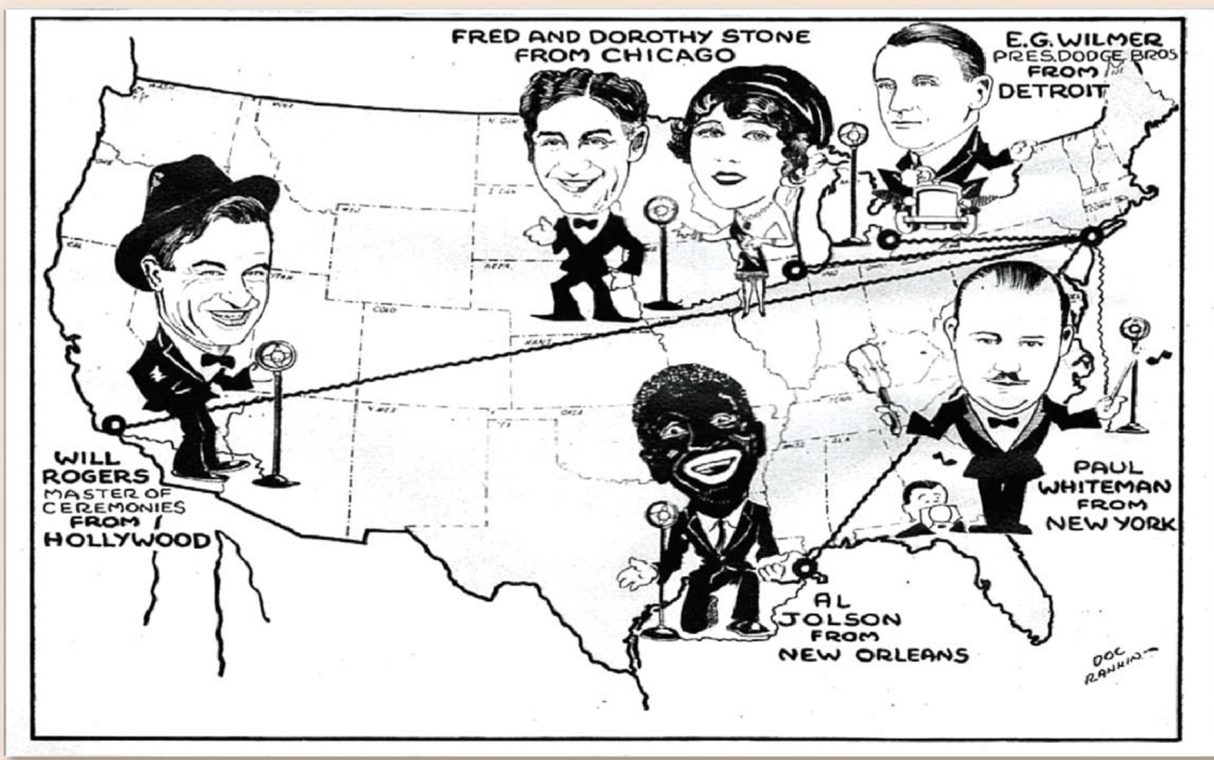
By 1928, the three original networks were going all out for election coverage. This was one of the "ad-hoc" networks set up for the project; parts of the network were telephone-quality.



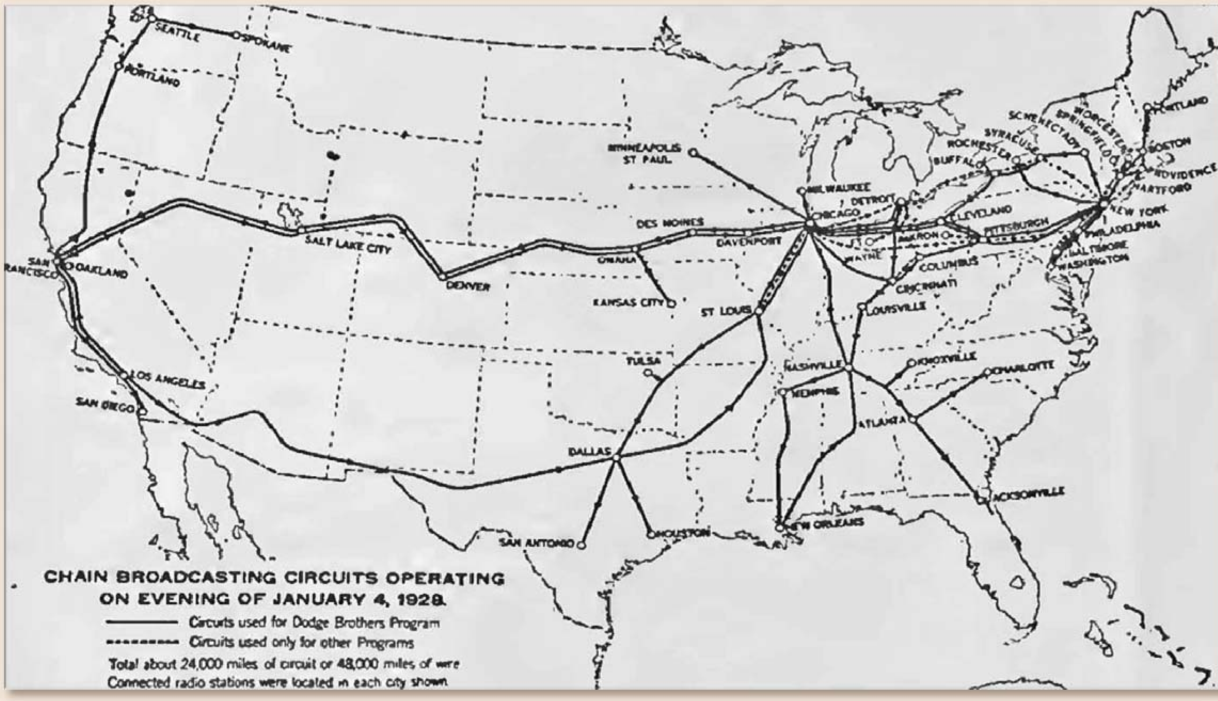
Network connectivity for 1928 Election
Bell Systems Technical Journal

The three networks were of course doing ‘one-way, top-down’ broadcasting. Everything was coming from New York. However there were a lot of stars on the Left Coast and the networks wanted to tap that potential. If the telephone circuits were the only impediment, money could be thrown at it. If it were simply a problem of collating far-apart broadcast presences into a smooth presentation, why not test the concept? An experimental broadcast took place in early 1928. Radio News reported: “A national broadcast said to be one of the most ambitious ever attempted was aired the evening of January 4, 1928. Will Rogers in Hollywood, Fred and Dorothy Stone in Chicago, the president of Dodge in Detroit, Paul Whiteman in New York, and Al Jolson in New Orleans were all on the same hookup which reportedly cost $1000 per minute for the three transcontinental telephone circuits.

“To bring these widely separated persons before the vast radio audience, estimated at more than 25 millions, approximately 12,000 miles of telephone lines were employed. Engineers of the National Broadcasting Company, in conjunction with the engineers of the Bell System, which supplied the lines across the country, worked on the arrangement for several weeks.”
Radio News, March 1928 This was another Long Lines ‘first.’



As to affiliate count, Radio World also reported that "NBC and CBS were neck and neck by the end of 1928. NBC was fighting back on the so-called 'elective method' whereby a single station picked and chose its affiliation depending on day-parts and program popularity. This practice had been started by WCCO, Minneapolis." *Radio World, December 1928*



Long Lines Traffic

A snapshot from the Bell Systems Technical Journal of January 15, 1929 provides the following profile as of the end of 1928: Most networks were operating six hours per day. NBC Red had 41 stations fed through 10,500 circuit miles. NBC Blue totaled 12, served by 3,600 miles. The AT&T map showed CBS with 41 stations (8,450 route miles), the Green Network of 8 stations (3600 route-miles); the Orange (NBC Pacific) with 5 stations at the ends of 1700 California wire-miles, the Brown Network (Don Lee) of 3 stations; 450 miles. There was even a short-lived Gold Network on the West Coast.

Over the years many more stations were added to the affiliate maps. AT&T provided each network with a 'Primary' channel, a 'Backup' circuit, an 'Order-Wire' and an optional telegraphy path. Other optional services included wire-photos (an early form of fax) and even switched-teletypewriter ("TWX"). AT&T left it to the networks to do their own splits and regional feeds. In July 1938 Radio News pithily summarized the state of network broadcasting: "It's a huge business for AT&T Long Lines."

The Networks Wander West

Until the late 1920's AT&T had no full-time program-transmission west of Denver. The only way to get program audio to the Left Coast was via a telephone call from Denver. This worked okay for news events but sounded pretty grotty on musical programs. On the Pacific side of the Rockies the audio was in good hands; Pacific Telephone and Telegraph Company was hip to program-transmission technology and provided almost 2000 miles of program circuitry (though at first *only* during non-peak-telephone hours).

NBC Pacific

NBC wanted a critical mass of stations from the outset so the network decided to leapfrog the mountains, building a West Coast subsidiary web. The "Orange" Network came alive in April 1927, from a newly-installed San Francisco switching center/hub. It fed stations in San Francisco, Los Angeles, Seattle, Portland and Spokane.

NBC San Francisco Switch Center *Courtesy: The Radio Historian*

To air NBC shows in the West, program material was sent by railroad to San Francisco where East Coast programing was "re-created"…one week later. (Live broadcasts of national importance were fed by telephone from Denver.)

West Coast-originated programming was important to the networks' image. There was a lot of talent under the sunshine, behind the palm trees. "The first nationwide broadcast from the West Coast to the East had been the Rose Bowl Game from Pasadena on New Year's Day, 1927, with Graham McNamee at the microphone." *http://earlyradiohistory.us/index.html*

Presumably this was via telephone, at least as far east as Denver.

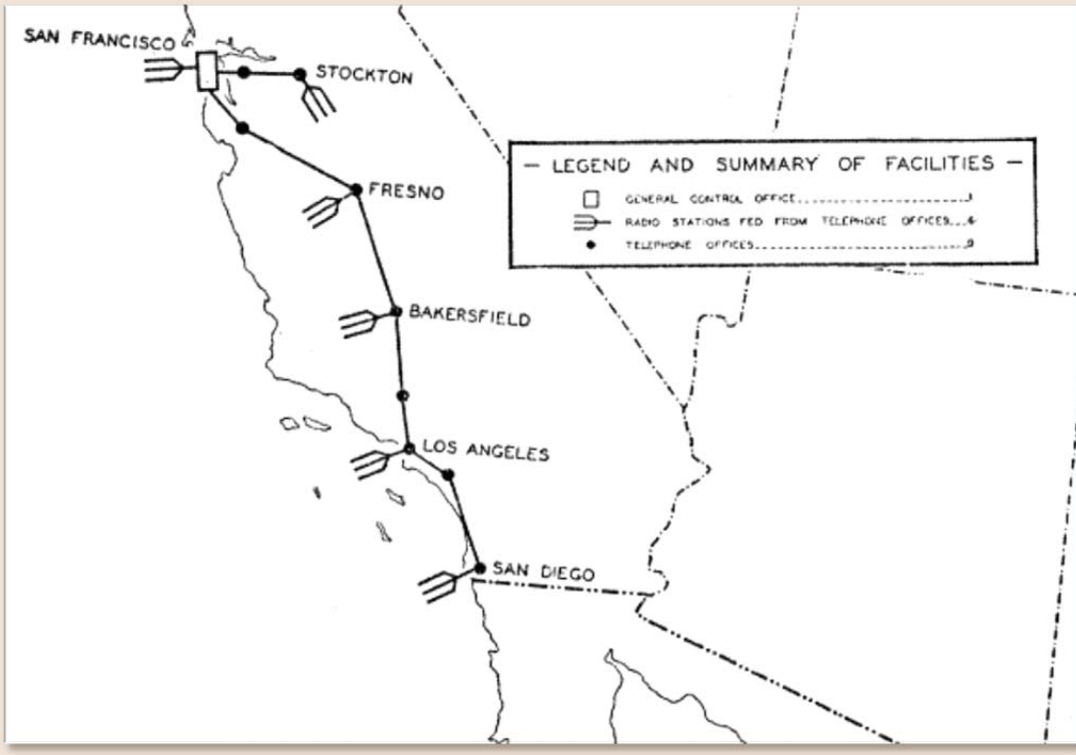
By 1929 AT&T had bridged the Rockies with a westward-bound program-quality circuit. Facilities were limited; NBC had to share a single circuit between Red and Blue programming.

For time-shifting reasons San Francisco continued to (re)-produce many East Coast shows. Eventually, reputable West Coast recording studios delayed network feeds for replay (obviating the need for redundant talent fees).

In 1936 NBC launched a second West Coast network ("Pacific Red," the former Orange network). A station shuffle followed; "West Coast Blue" replaced the now-defunct Gold network that had been operated by one of the (other) "American Broadcasting Companies." The new Blue circuit terminated in Los Angeles rather than San Francisco. This meant it was no longer necessary for Hollywood stars to travel to San Francisco to go live, or for the network to pay for a program loop from Los Angeles to San Francisco.

Columbia West Coast

Columbia began its own Pacific expansion by contracting with auto dealer Don Lee; himself a broadcasting power, with San Francisco and Los Angeles stations and a network that reached to Washington State. In July 1929 the Don Lee stations became "affiliates" of Columbia. The West Coast network was re-named the "Don Lee-Columbia Chain."



Don Lee Network *Courtesy Bell Telephone Record, 1934*

San Francisco's Lee-owned KFRC became Columbia's West Coast switching facility. In addition to its Pacific stations, Don Lee fed the rest of the network to the East in the late hours after New York studios were closed. (In spite of the reverse time-zone situation, several West Coast programs gained great popularity on the national network.)

The eventual demise of the Columbia-Don Lee agreement said a lot about the way Paley did business. In structuring the affiliation deal with Lee he had given himself an escape route; it would be easier to abrogate an *affiliation agreement* than to fracture a more closely-tied *sub-network arrangement*. Without notice to the Don Lee group, Paley purchased KNX Los Angeles in 1936, displacing Lee's KHJ as "Columbia-Los Angeles." Since KNX and San Francisco's KSFO had a close relationship, Paley also obtained a right to purchase KSFO, planning to move to that station from Don Lee's KFRC. Paley couldn't buy KSFO, so instead he grabbed KQW, bumping KSFO from Columbia. Loyalty apparently meant little; this was business.

Don Lee was confounded. Long-time partners jumped ship and, tired of the East Coast way of doing business, formed their own "California Radio System." (It didn't last very long.)

Mutual

Meanwhile, the new "Co-Op Network" had been formed, in 1934, and looked like it had legs. The network needed West Coast affiliates at the same time Don Lee was seeking a major-network affiliation. A long-lasting mutually-beneficial relationship began with the launch of the "Don Lee-Mutual Network" in late 1936. Mutual's AT&T circuit terminated in Los Angeles rather than San Francisco, so Lee's KHJ once again became a West Coast primary station.

Hooray for Hollywood

By the mid-30s the networks were building Hollywood hubs, and San Francisco's days as a switch center and program hub were numbered. The "NBC Hollywood Broadcast Studios" opened in 1936; two years later NBC built a completely new broadcast complex and moved its West Coast management team from San Francisco to Hollywood.

For its part, in 1938 CBS opened "Columbia Square" in Hollywood, based around KNX. The powerhouse station housed CBS's transplanted West Coast switching hub.

Mutual's own commitment to Hollywood was completed in 1949: "A new building has gone up in Hollywood…the new home for the West Coast operations of the Mutual and Don Lee Broadcasting Systems, one of the most complete installations of its kind ever to be erected." *Radio-TV News, 1949*

Reversible Circuits

By 1936 all network circuits were terminating in Los Angeles, further reducing San Francisco's role. With national network lines in Los Angeles and with the investment made there in programming, the major networks now sought to reduce the costs of hauling Hollywood-based shows back East onto the network. AT&T came up with a solution.

It was 'simply' a matter of reversing the direction of the amplifiers and repeaters on the westbound channel, in several dozen repeater locations across the country…*all at the same time*. Path-reversal was originally done by engineers flying patch cords; the switching coordinated by the use of an Order-Wire circuit. Fifteen seconds were allowed for everyone to re-patch; this was usually during a "Chain-Break."

The entire program path was reversed by this method and bad marks to the engineer who missed a switch or mis-patched, because he could take down the entire network or create a nice feedback howl. With switching accuracy and reduced switch-time in mind, Long Lines now engineered a remote-controlled relay bank that operated via a phantom voltage imposed on the line *from the originating station* (the line-reverser was controllable from either direction).

"Hysteresis was added so the relays wouldn't switch on a burst of impulse noise. That hysteresis was fine for cable; for open-wire application a more sophisticated system took into account the higher transient environment in the open-wire domain, as well as the fact that open-wire inherently had higher leakage to ground. *Info from The Bell Telephone Record April, 1941*

(By the way it's also likely that the technical characteristics of the fast-reversed path didn't exactly match those in the normal direction because of the individual forward conditioning in the various repeater stations. So reversing worked best when engineers had several hours' notice to line up amplifiers and equalizers in the reverse direction.)

Adding direction-reversal to the new line meant that for the first time shows originating in Hollywood could routinely head east for national distribution ("East-bound" meant New York for CBS and Chicago for NBC). Many Hollywood programs had to travel all the way around the horn to be heard locally on the LA affiliate. Shows went east on AT&T lines, were turned around in the East and re-fed to the network. Listeners with good ears easily detected the difference between a locally-originated KNX program and one routed through this long network configuration. (Today there exist program collectors who can identify the spot along the network where a recording was made.)

This reversing facility was still in use in the 1950's; we can recall hearing NBC Monitor taking the famous "pause to reverse our circuits" before switching to California.

The reversible circuit got a workout during World War Two, when Short-Wave reports from the Pacific Theater were directed east to the networks from Pacific Coast Short-Wave receivers.

Since these reports were live (remember…no recording allowed) the news anchor gave a verbal cue and we'd all wait while the clicks along the line signaled path-reversal and the Pacific short-wave receiver came up.

National Coverage?

It's simplistic to think of the national radio networks as providing country-wide coverage. This certainly wasn't the case for the first decade. Despite lip service that "national networks helped achieve cultural unity," this was a goal more admirable in the selling than in the doing.

The networks delivered 'full-quality' transmission (100 to 5,000 cps) to the dense population centers; other areas including the Deep South and sparsely-populated regions of the West) were served by circuits of narrower-bandwidth audio (it was less-expensive).

Another contradiction surfaced under the networks' tactical tents. The nets were out to destroy local radio, calling it technically inferior and citing the absence of network-quality programming as a reason to take these smaller stations off the air (thereby of course enhancing the power of their own big-signal affiliates). Then…when business reasons dictated "full" national coverage, they grandly wooed these smaller stations, to fill in underserved areas.

It isn't hard to agree with this comment: "Despite its image as uniform, consistent and singular, the (network) system was limited, unstable and hybrid." *Points On the Dial, Alexander Russo*

Defining Marketing Reach

The early driver of radio expansion had been receiver sales. Fully 40 percent of the pioneer broadcasters were set manufacturers. Once the market for set sales was saturated and other services/products were being promoted, ‘radio markets’ were constructed following the model of the newspaper…the focus was on large population centers and, within, on high-income areas.

Radio coverage was defined by marketers who tied together advertising, distribution and consumption capacity. As a practical solution the “split-network” became commonplace: when advertisers refused to pay for clearance in markets they didn’t want, the networks had to provide alternative ‘fill’ programming to those markets.

This led to major friction between advertiser and networks (who pushed back because of the production costs), and between networks and stations (affiliates wanted dependable national programming not at the whim of the sponsor).

There was also a concern on the advertisers’ part about marketing a product where it wasn’t welcome. These concerns outlived radio’s mass-market popularity and still existed in the 1960’s. (In the 1960’s WCCO provided a network that fed Minnesota Twins baseball play-by-play to several states. As a control room engineer, I remember having to send a different Hamm’s Beer commercial to Minnesota’s Iron Range stations; that commercial didn’t mention the Hamm’s ‘new *aluminum* can.’)

The “Other “National” Networks

Several alternative “start-up” national networks were now floated…but most of those boats ended up wrecked on the rocks of high transmission costs. One of the several networks labeled “ABC” was announced in 1929, with WMCA as the primary station. The initial line-up was to include stations as far west as St. Louis. It fell apart because of a lack of advertisers. (Jim Ramsburg relates a wonderful “ABC” story in a later chapter.)

Ed Wynn announced the Amalgamated Broadcasting System (“ABS”) in 1933. He had great ideas and commitment from several stations, but the network was short-lived (he and his investors were by now hearing rumors of the new Mutual Network).

RadioCraft magazine observed in 1935: "Although the NBC and CBS networks are the two important broadcasting networks in the USA, other networks are in existence; some of them affiliated with either the NBC or CBS networks on a part-time basis….Don Lee had 12 affiliates...A network of Wisconsin radio stations had 7 affiliates; it was associated with CBS. The Mason Dixon Radio Group consisted of 5 stations and had no other network affiliations. It served Southern states. The Michigan Radio Network totaled 8 stations and had no other network affiliations.

“NBC was heard over 5 stations in the New England Network. The Northern California Broadcasting System was just a couple of stations with no other network affiliations. 4 stations were part of the Southern Californian Network; no other network connections. A Southwest Network fed 11 stations and was associated with CBS. The famed Yankee Network had 11 stations. Iowa Broadcasting Company included 3. Such was the state of Regional Networks as of December 1933.” *RadioCraft Feb 1935*

The saga of John Shepard and the Yankee and Colonial Networks is deserving of an entire journal…and indeed several have been written. Shepard was a maverick, a visionary, a salesman and a hard-headed and inconsistent businessman…but he had the power of a group of significant stations behind him. From the way he played the major networks, one would almost think he had been lurking in their Board rooms instead of beginning his career as a Boston broadcaster. Shepard’s dealings (first with CBS; then NBC and Mutual) caused some major and minor changes in Boston network affiliation…including an almost-move of WTIC from Hartford to Boston. His dream of a national sales network was derailed by the launch of Mutual in 1934.

Within a Regional Network, geographically-related stations grouped together to serve areas of common interests and realize the economies of scale of the larger networks. *Regional* live-program distribution was an arena in which the big nets couldn’t operate at a profit. So it wasn’t surprising to note that some regions had more than one network operating successfully.

That said, we note there were many “unwired networks” collaborating on a sales-only basis. (Unwired networks in fact accounted for a significant segment of advertising revenues.)

Cost of Coverage

It’s now important to underline the economic reasoning behind the importance of smaller networks, whether un-wired sales nets or regional program chains.

Broadcasters had developed a station-value model in use today: “reach-cost-per-listener.” High-power stations had a huge economic advantage in these equations. Wide-area coverage allowed them to charge more for air-time…while delivering a larger market area to mine for potential advertisers. Especially at the big stations, more revenue meant better programs; better programs meant more listeners; more listeners meant higher rates and so on.

For smaller stations airtime sales, whether in program blocks or individual “announcements,” weren’t always enough to offset operating costs. The mathematics caught up with many. There were only so many minutes of broadcast time per hour. Most stations operated in markets that, driven by their local economies, imposed a practical limit on ad revenues. (There was also a matter of how *much* of each broadcast hour could be commercial matter; that limit was even codified at one time). There were no NTRs, no SCAs, no tower rentals. Airtime sales were it.

The only way to defray costs was to spread them over a number of outlets.

“Too Big to Fail?”

The interest in regional network coverage to augment (or even replace) the national distribution footprint of the major networks addressed in part the concerns of those who stood against the “country-wide, one-size-fits-all” network approach. In 1928 Radio News editorialized that “the days of Chain Broadcasting may be over.” They cited the problem with time zones and the disruption on listener’s lives when a popular live program originated on East Coast time.

The commentary suggested “too many programs of sectional interest were broadcast to *areas where there was no real interest.”* Their solution: *AT&T should split network service into regions. Taken from Radio News, Feb 1928* (italics added)

In Radio World for January 1929 we learn that the Federal Radio Commission (“FRC”), in response to listener objections about network duplication, particularly in the Midwest, had issued General Order 43 of September 8 1928. It mandated that **‘Clear-Channel’ stations affiliated with a common network must be separated by at least 300 miles…**except for one hour each evening (presumably near sunset).

The FRC also encouraged *synchronous broadcasting* by permitting exceptions to the above rule for synchronized operation.

Broadcast interests (managing their federal oversight even then) created delay after delay in the Rule’s implementation…until the Order was finally canceled.

In 1933 there were 9 or 10 regional networks; the 1941 “Radio Annual” directory lists 38 regional networks…some wired; some sales-only. Most states were represented, some with more than one network. Nearly all the regionals were fed by a Primary or “Key” Station, which wrote shows and sent scripts to smaller affiliates for production by their own local staffs.

The Key Station often passed along its own affiliated-network feed…but interrupted that feed when programing of regional destination was to be inserted. The AT&T Long Lines feed was terminated in the station’s equipment but fed also to a switcher, to route the network farther down the line to any stations affiliated with the mother network. Usually a separate announce booth/control room was used for regional network programming.

In larger Key stations several different broadcasts might be fed simultaneously to different affiliates in a given region, so routing could be challenging. The solution was a version of the same technology used by the big networks: “salvo switching” via a “Pre-selector.” This was an identical dual-bank crossbar switcher. As the split-time approached, the operator ‘pre-selected’ the new routing combination on the “standby” section of the switch bank. At switch time, he’d push one button and the entire new-feed combination was transferred to the new routing.

Many affiliates came aboard these regional networks to gain access to professionally-delivered regional news and fast-decay information (commodities quotations and weather by region come to mind).

But live reports required some form of connectivity. It could be done several ways: An AT&T program channel…off-air relays…even telephone calls. The following chapter details some of these relay alternatives.

"The Radio Annual" put it all in rather circular fashion: "Steadily increasing growth of regional network billings indicates that more and more national advertisers are directing their campaigns in high-spot markets.

With the advent of purchasing the time actually wanted, tailor-made talent of particular appeal to the specific area and aggressive marketing policies of the individual networks, the advertiser is provided with sales impetus in…areas where sales can be produced.

"As the majority of these networks are sufficiently flexible to provide coverage where and when the client wants it, it is believed that the trend in 1941 will be of greater application to selective markets as exemplified by regional networks." *Keyes Radio Annual, 1941*

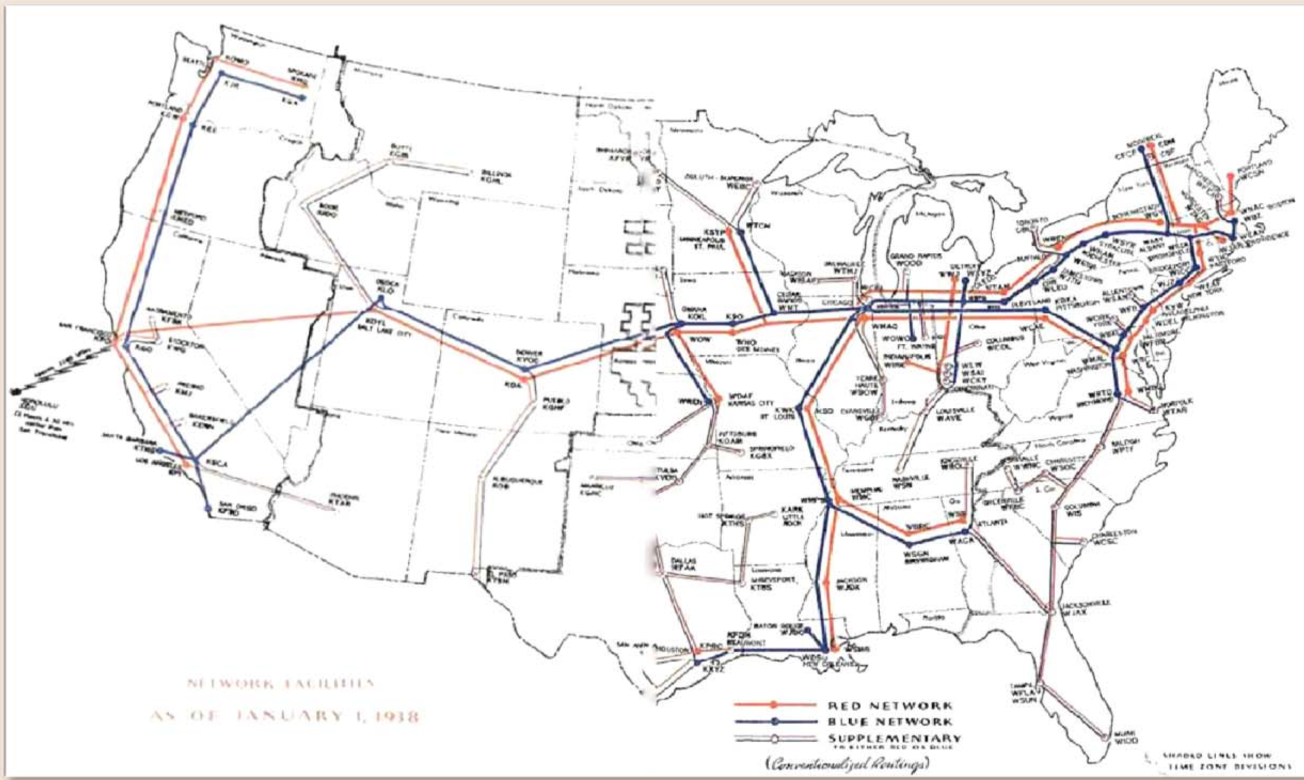
A strong driver for (ad-hoc) regional networks was sports play-by-play. Early on, big stations found they could charge more for network sports coverage and, by marketing to a sports team's entire franchise area, help to stimulate game-ticket sales. This one was a no-brainer and these sports networks still operate profitably today. (Most sports networks began using AT&T Long Lines and migrated to satellite along with everyone else.)

As to sales, station salesmen (there were no women) presented a "joint rate card" showing the cumulative coverage of all stations. Commercials were aired on all regional-network stations or on a select group of these stations chosen by the advertiser.

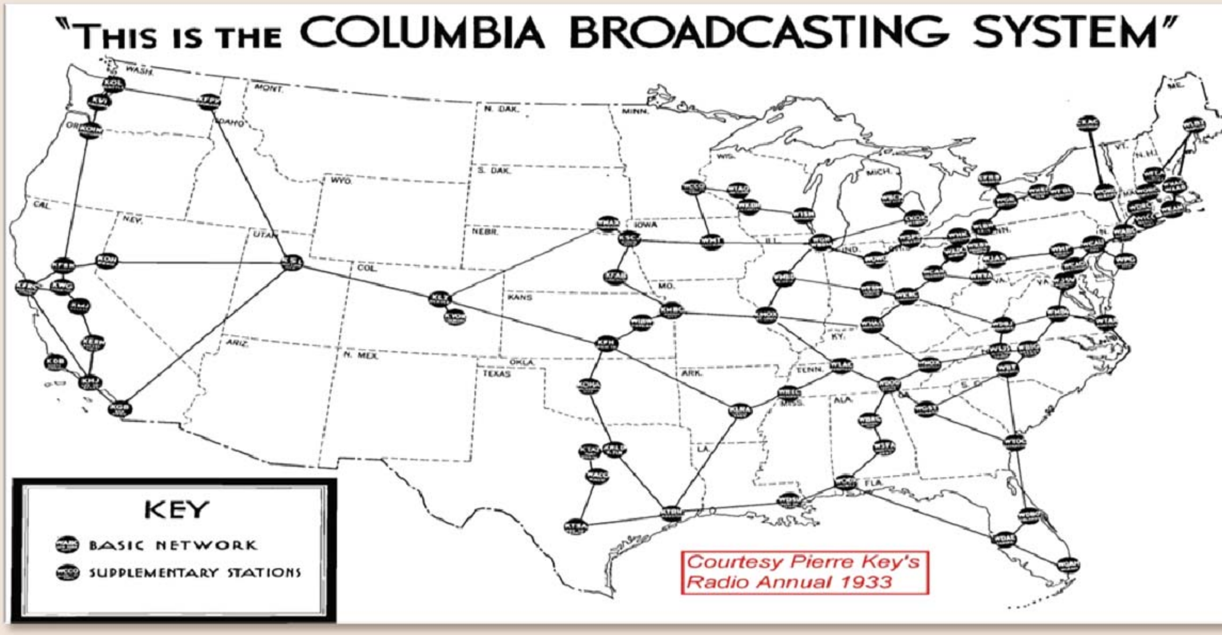
For those interested in customization and granularity, the regional networks provided a cost-effective solution. Unwired networks did have one logistical problem, in trying to "simultaneously" clear programs purchased by a major buyer.

The big nets themselves split for (unwired) sales and regional-coverage purposes. For example, in 1942 you could buy participating time on the Blue Network (soon to be ABC) in more than a dozen configurations from "Blue Basic" to "Blue Pacific Coast Group Overseas Services (Honolulu/Manila/Cebu)." Each of the dozens of unwired networks had its own group rate card, and savvy time buyers mixed and match markets of appeal, thus circumventing the cost of inefficient advertising on the national network.

But the big networks were still the main arteries and their reach was unparalleled. Here's a poor-fitting match of two maps showing NBC's coverage in 1938. It looks like a national network… but for any given program it sometimes looked less impressive:

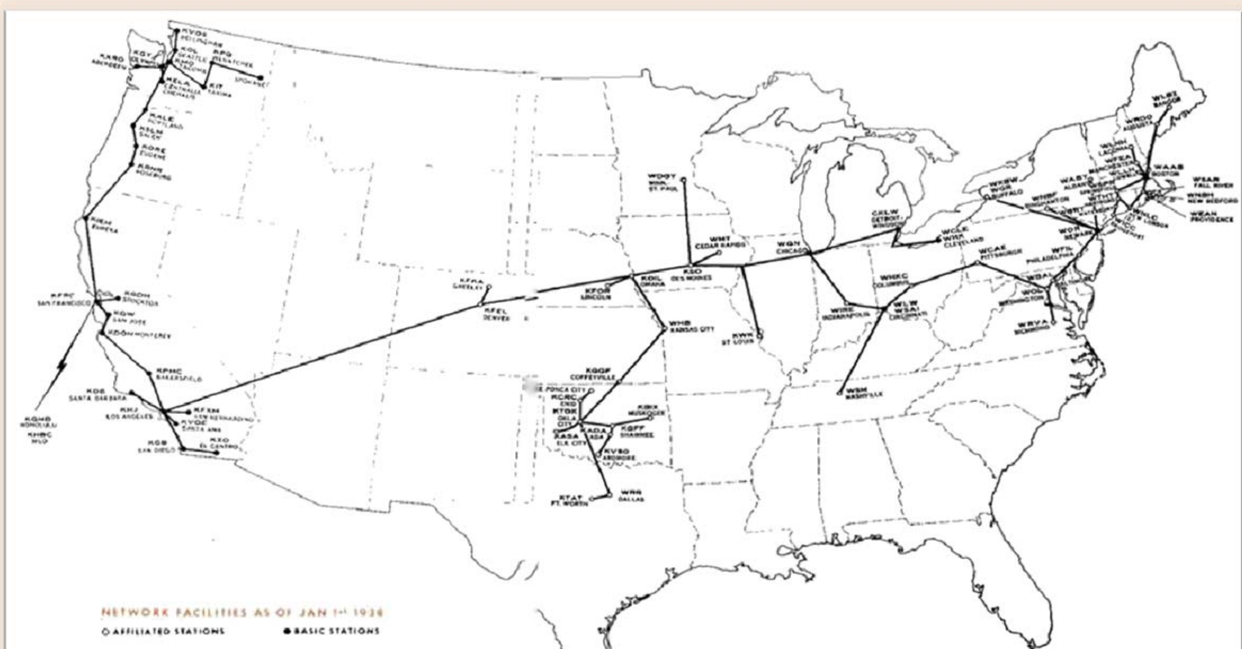


Courtesy KEYES Radio Annual 1938.



CBS wasn't far behind in affiliate count. Networks relied on the bigger stations as their key outlets and granted them a certain degree of protection from smaller would-be affiliates.

And a Mutual composite map for 1938: *Courtesy KEYES Radio Annual 1938* Mutual would grow to having the largest affiliate count because of the large number of smaller affiliates.



CHAPTER SIX

When the Wires Didn't Do The Job: Alternatives to the Long Lines Network

AT&T Long Lines found program transmission to be a lucrative business. It was fun to have a monopoly. Long Lines charges were a major cost item for the big networks…and a major roadblock for start-ups.

In the previous chapter we noted how some stations operated close to the bone and found at least mythical salvation in the idea of sharing operating costs with affiliated outlets. But AT&T transmission costs could be a stark reality. For this reason and because the reach of wire-lines wasn't ubiquitous, broadcasters looked for distribution alternatives. Options included syndication by transcription or simulcast by radio-relay. Each idea was evaluated, adopted, or discarded as impractical. (Of course, in distant areas not reached by wire (think: International Broadcasting) the only practical solution was Short-Wave radio.)

"Off-line Distribution"

Syndication was not a new idea; in their pre-network days of the 1920's, Amos and Andy distributed their show from Chicago on 78 RPM discs. The standard for transcribed programs evolved into the 16-inch, 33-1/3 RPM disc (the "ET"). Its specifications were developed as part of the early "talking pictures" revolution: prior to sound on film, the ET was synchronized with the film to give the movie its voice (the ET's speed/size matched the duration of a reel of film).

But the quality of transcriptions wasn't consistent. The physics of disc velocity meant there was a gradual loss of highs as the stylus approached the disc center. Playback of programs segmented by multiple discs was finessed by recording every other disc "inside-out" so the change in highs wasn't as noticeable when one disc followed another.

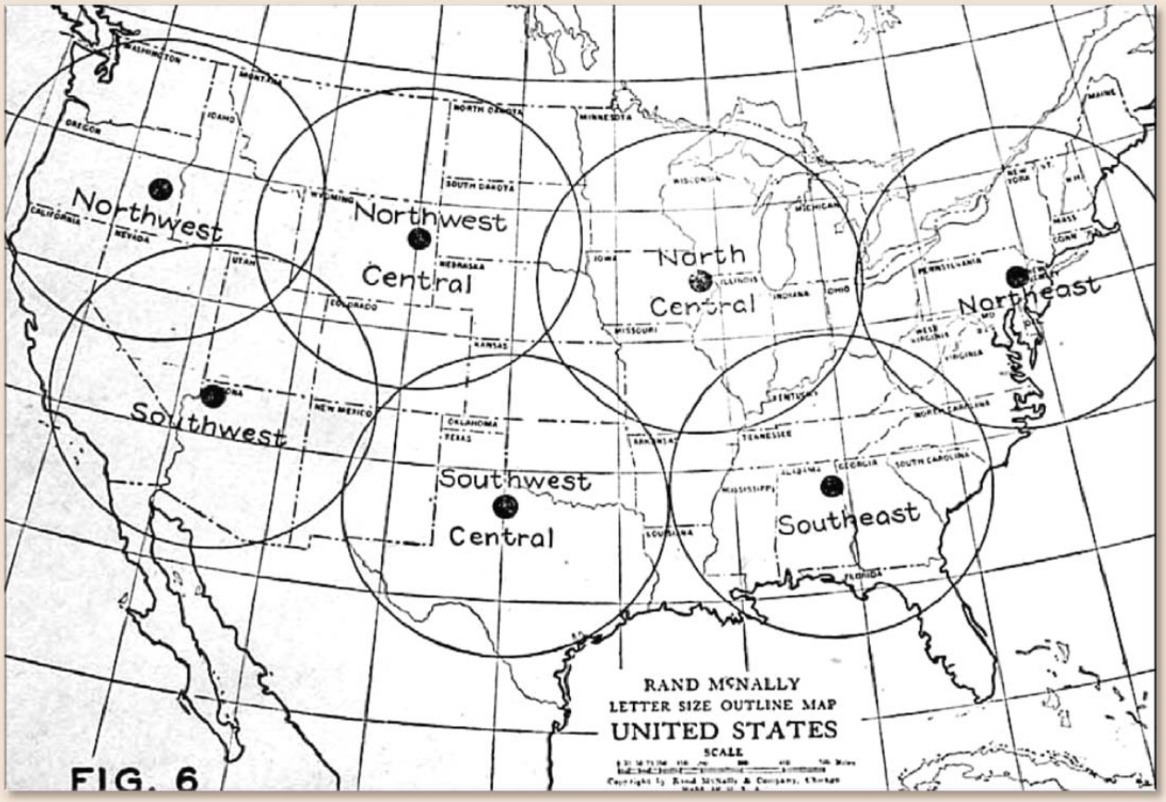
Finally, transcribed programs weren't always aired at the same time, so audience measurement was difficult.

Other transcription technologies included wire and (eventually) tape; even embossed film (the "Pallophotophone"). Underlying it all was the concern about 'timely' programming reaching the affiliates…or sometimes being lost in the mail. When networks finally permitted "Reference Recordings" of their shows and copies were made for distribution to the Armed Forces, a vast library of ETs was created; it is these recordings and "Network Reference Recordings" that survived as the backbone of the "Old Time Radio" hobby.

"Radio" Alternatives

Radio News for April 1931 suggested that seven national Long-Wave superpower stations could supply substantially complete national coverage. The article reports that 200 kc broadcasting experiments in the United States "have shown no fading inside of 300 to 350 miles."

The Radio News story suggested seven stations necessary to cover the country could be located in Oregon, Wyoming, Illinois, Eastern Pennsylvania, Northern Alabama, Northern Texas and Northwest Arizona. Power levels from 100 kW to 1000 kW were proposed.

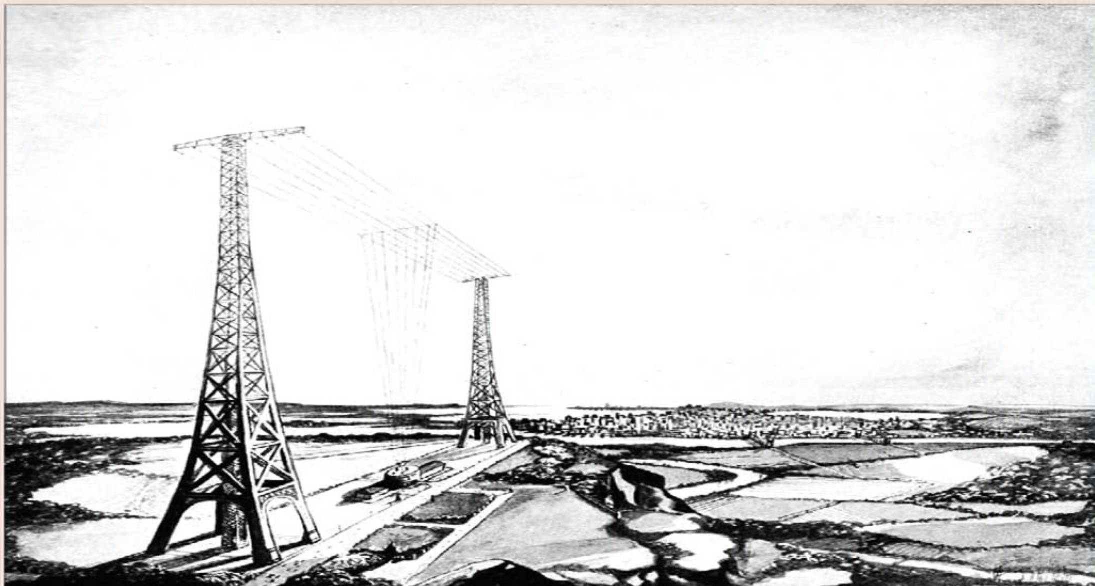


Long-Wave national coverage *Courtesy Radio News, April 1931*

The seven would operate on separate frequencies with about 70 kc protection. "Partial Synchronization" was contemplated. It was also envisioned that “a single 10 KC channel might be derived with complete synchronization.”

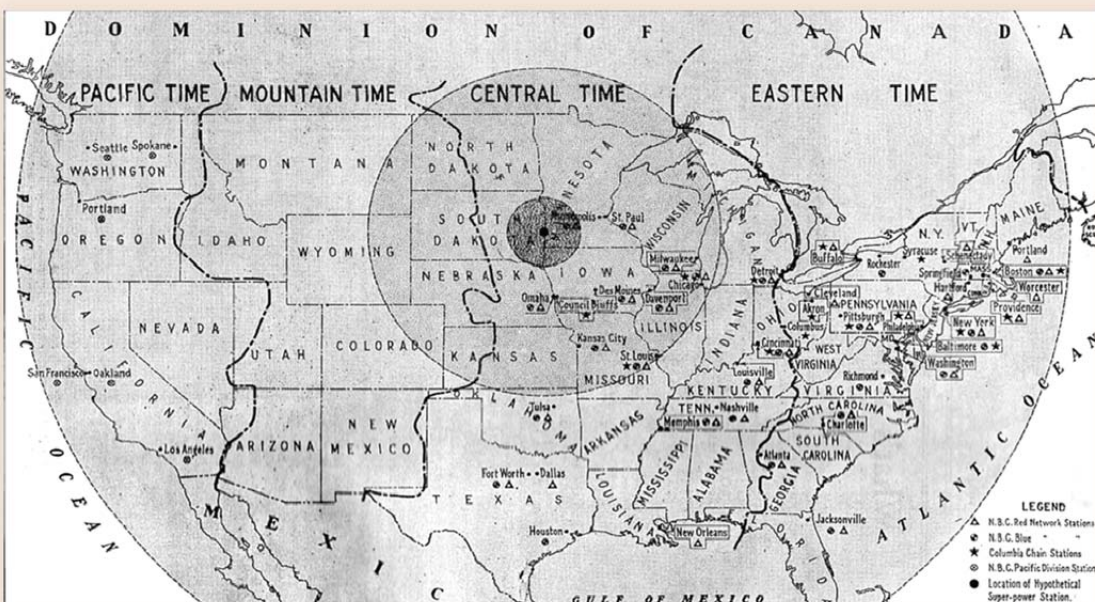
It turned out that, as a practical matter, Long-Wave broadcasting was a good fit for smaller countries…but the United States was too big. Still, several legitimate Long-Wave transmission tests were conducted during this period.

And of course someone had to propose a single “big-stick” solution. That idea was discussed in Radio News, Feb 1928. Proponents thought full-country coverage might take oh, say, only about 1000 kilowatts of RF, from a radiator on the Minnesota/South Dakota border.



A Super-Broadcasting Station of the Future?

To cover the whole country by direct waves, towering antennas 800 feet high, located in a central radiating position, would be fed by a 1,000-kilowatt transmitter operating on 1,500 meters, according to Lieut. Wenstrom's plan. This system would not rely on the sky wave with its effect in producing fading in distant receivers



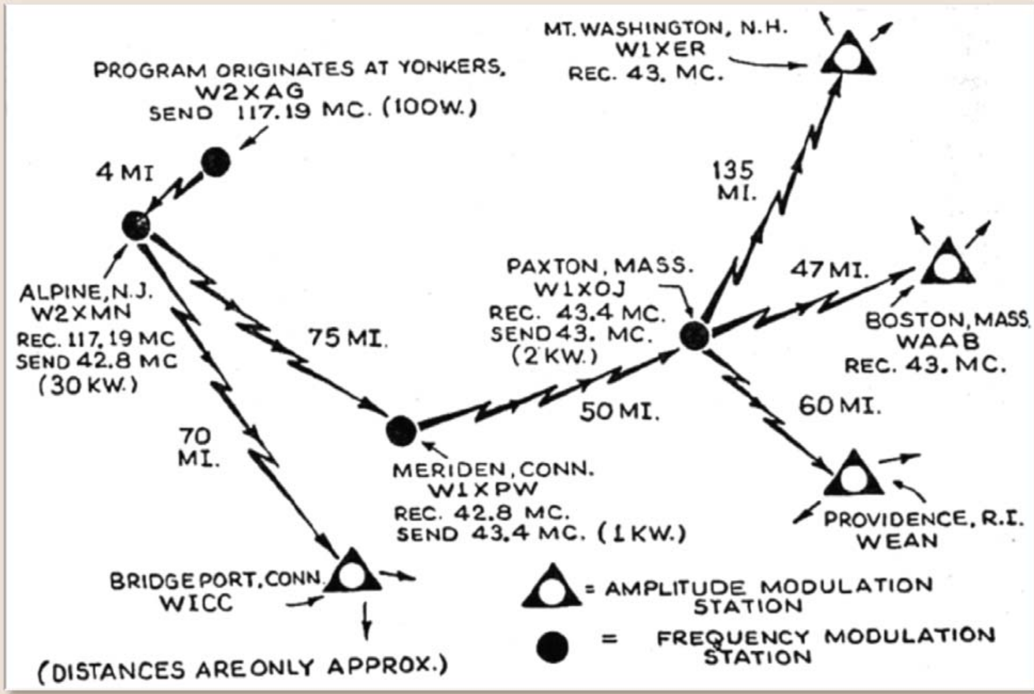
A fascinating idea for a synchronized radio network appeared in the February 16, 1929 Radio World. Two synchronized 50-kilowatt national-coverage Short-Wave signals were proposed; their "difference frequency" would generate a stable Medium-Wave carrier, modulated locally. Programming would ride on one of the Short-Wave carriers.

These proposal and others assumed that one national voice was all that was needed; they completely misread the realities of the competitive broadcasting business.

"Off-Air" Relays

By the 1940's, distribution included FM relays. The best-known example was the Yankee Network. Here are snips from FM Magazine: "The Yankee Network…embarked on a program of experimentation with frequency modulation in the Spring of 1937…The completion of the new antenna at Yankee's 50,000-watt FM transmitter, W1XOJ, represents over two years of experimentation and FM broadcast operation. This station, located at Paxton, Mass…operates from the Boston studio through an FM radio link…When this project was planned, no 50-kw equipment had been built for the frequencies assigned to FM experimentation. Furthermore, no antenna system had been designed or constructed with radiating efficiency high enough to ensure the desired performance.

"It was estimated at the outset that a transmitter of 50-kw capacity located near Worcester, Massachusetts, using an antenna with a…power gain of five or more, would serve a residential and rural population to a distance of about 100 miles. Further, it was estimated that the large cities would receive sufficient field intensities to insure satisfactory (coverage) within 50 to 75 miles, depending on topographical conditions between the station and the area in question. "On January 15, 1941, the new antenna was put in operation and reports…show that the performance fulfills all expectations. With that breakthrough, tests were originated at Armstrong's W2XMN Alpine NJ and relayed…across New England via… Meriden Connecticut (W1XPW) and…W1XOJ." *FM Magazine," March 1941*



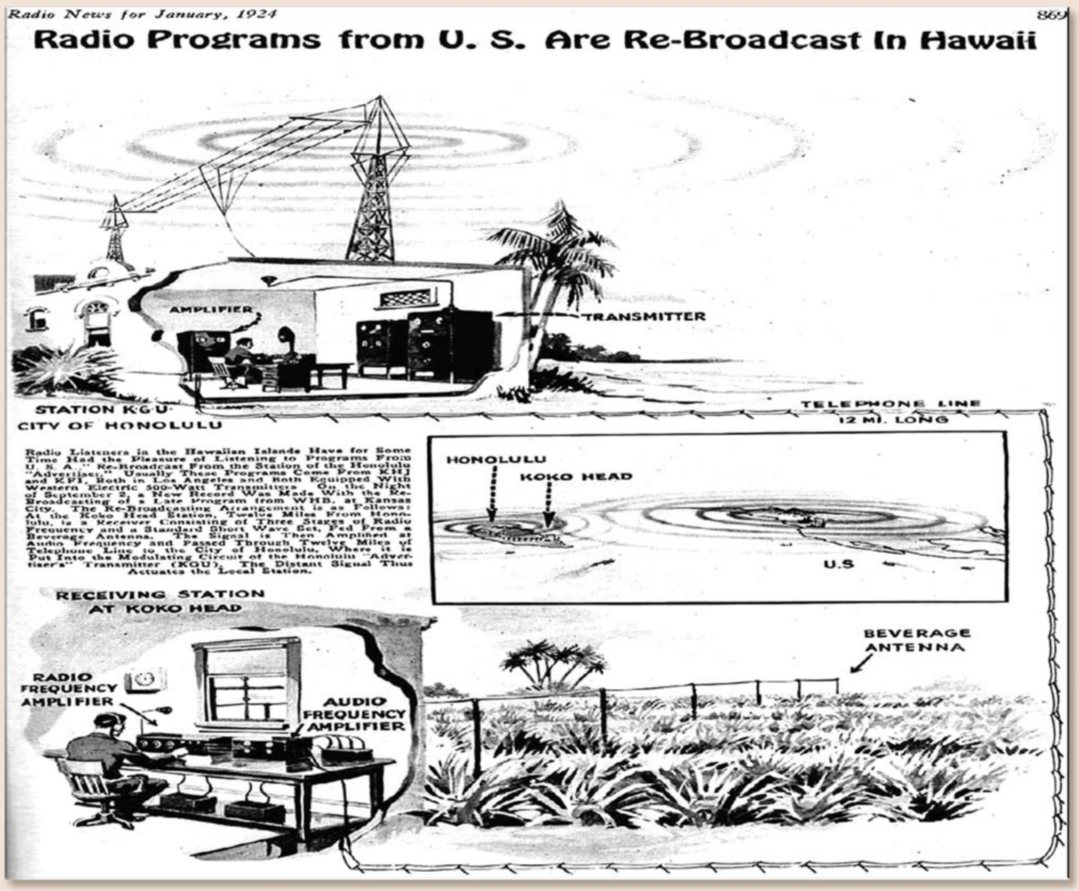
FM Magazine March 1941

The November 1941 issue of FM Magazine noted: “The prospect of improved program service for New York’s FM listeners came closer this week with the announcement that The American Network, FM’s first chain organization, will shortly file its application for a key outlet in New York City. The American Network plans the eventual establishment of a coast-to-coast web having outlets in more than 40 principal cities, with approximately 75% of the national population living within the proposed service areas. Already operating are two of the network’s stations in New England, W43B and W39B, which have a combined coverage capable of reaching 93% of the population in those six states.

“As soon as W53PH. Philadelphia makes its debut as that city’s first FM station, it will be another outlet of The American Network. Establishment of a New York station would provide a valuable link, giving continuous FM network coverage along the entire northeastern seaboard. Other stations of the chain already on the air with daily schedules, but not as yet linked up for program exchange, are W47NV Nashville, W55M Milwaukee, W45D Detroit, W51R Rochester, and W45CM Columbus. In addition, W41MM Mount Mitchell, NC, will be operating shortly.” *FM Magazine November 1941*

Some AM stations built their own off-air mini-links. Dr. George Brown remembers that WHA in Madison fed its satellite WLBL in Auburndale Wisconsin; WLBL used a Beverage antenna to receive solid copy from WHA.

Radio News published a story in 1924 describing KGO Honolulu's use of a Beverage antenna for relay of KFI and KHJ (once even WHB).



Radio News 1924

The Short-Wave Universe

Thomas White has written the definitive work on early radio history in the United States. He says: "Another alternative to telephone lines briefly looked promising. Experimenters in the early 1920's, led by amateur radio operators looking for more spectrum space, and aided by the development of vacuum-tubes transmitters operating at much higher frequencies, came across the fact that low-powered Short-Wave signals traveled remarkable distances. Due to their ability to bridge wide gaps…Short-wave transmissions appeared to offer an inexpensive and flexible method for interconnecting widely scattered stations. Westinghouse in particular began investigating whether Short-Wave transmitters could link its broadcast stations into a national network." *Thomas H. White* http://earlyradiohistory.us/index.html

In 1924 Short-Wave had been added to the broadcast mix as a class of "experimental relay broadcasting." Short-Wave became a great tool for overseas links for news from abroad, and as a distribution system to extend the networks to international markets as we'll learn.

Short-Wave seemed a big deal to many stations. Some may have been hedging their bets to see if the frequencies around 100 meters ended up as a new "broadcast band." Stations operating Short-Wave in the late 1920's/early 1930's among others were KDKA, KFKX, KHJ, KMOX, KNX, WABC, WCFL, WGY, WHK, WJR, WJZ, WLW, WOR, WLW, WSM, and KGO.

A 1944 Radio World article explained how the Westinghouse "radio-relay-landline" hybrid linked six stations: WBZ Boston…was fed via land-line to WGY Schenectady. There a Short-Wave transmitter (100 meters) relayed the signal to KDKA Pittsburgh. KDKA…sent the signal (on 98 meters) to KFKX in Lincoln Nebraska, as well as to station 2AC in Manchester England. KFKX uplinked a 108-meter signal to KGO in San Francisco.

"These messages definitely placed the stamp of success upon the experiment, for two stations over 7000 miles apart had incontrovertibly received and been able to rebroadcast the same program without the use of any material connection." In another experiment, a KDKA spokesman noted that the station was able to dramatically improve reception toward Cleveland from Pittsburgh, by simulcasting KDKA on 80 to 100 meters. They posited the country would benefit from *"two classes of broadcasting stations: stations national in scope (presumably Short-Wave) and those serving local markets."* Westinghouse felt the use of Short-Waves for domestic broadcasting could open up many new broadcast frequencies. *From Radio World, March 1944 and from KDKA files.* (italics added)

Network Short-Wave Program Distribution

Early on, the reach of Short-Wave had been under-appreciated, but by the end of the 1920's International Short-Wave was well-defined and pretty slick. Many countries implemented high-power Short-Wave as an instrument of national policy; many of them on the air into the 2000's.

The demand for International "Broadcasting" began in earnest when the major networks began to eye the countries of the Southern Hemisphere as goals for expansion. (The totalitarian countries had been putting great emphasis on Short-Wave broadcasting to Mexico and South America, where many lived in isolation and had few other sources of information.)

U.S. communications companies had been an important force in Latin America, harking back to the days of the United Fruit Company's private telegraphic messaging network. The networks believed participation in South America's communications might mitigate the feelings of interventionism in President Roosevelt's "Good Neighbor" policy. As well as improving Pan-American understanding, Inter-American contact would be useful in enlisting support should the United States enter the European war.

Besides…the networks saw South America as a natural market for re-purposing their programming…for profit of course.

In 1940, executives of the Columbia Broadcasting System quietly visited 18 Latin American countries and made arrangements for 64 broadcast stations in those countries to become associated with the new CBS International Network, carrying regular day-by-day broadcasts of specially built programs (CBS scored the publicity, but NBC was there several years earlier).

CBS had been transmitting Short-Wave since 1930. In 1932, Short-Wave station W2XE, formerly WCBX, came on the air and plans were to build 250 kW stations WCBX and WCRC.

NBC had been using stations W3XAL, W8XK, W2XAD and the W1XK as relays to Central America, South America and Europe (a steerable antenna directed about 120 KW toward Alaska). In 1942 NBC upgraded WRCA-WNBI to 50,000 Watts at Bound Brook New Jersey. (Bound Brook was also the site of the WJZ transmitting facilities. The patching system for the Short-wave transmitters cleverly provided a way to use those facilities as a backup for WJZ.) *Proceedings of the IEEE, March 1942*

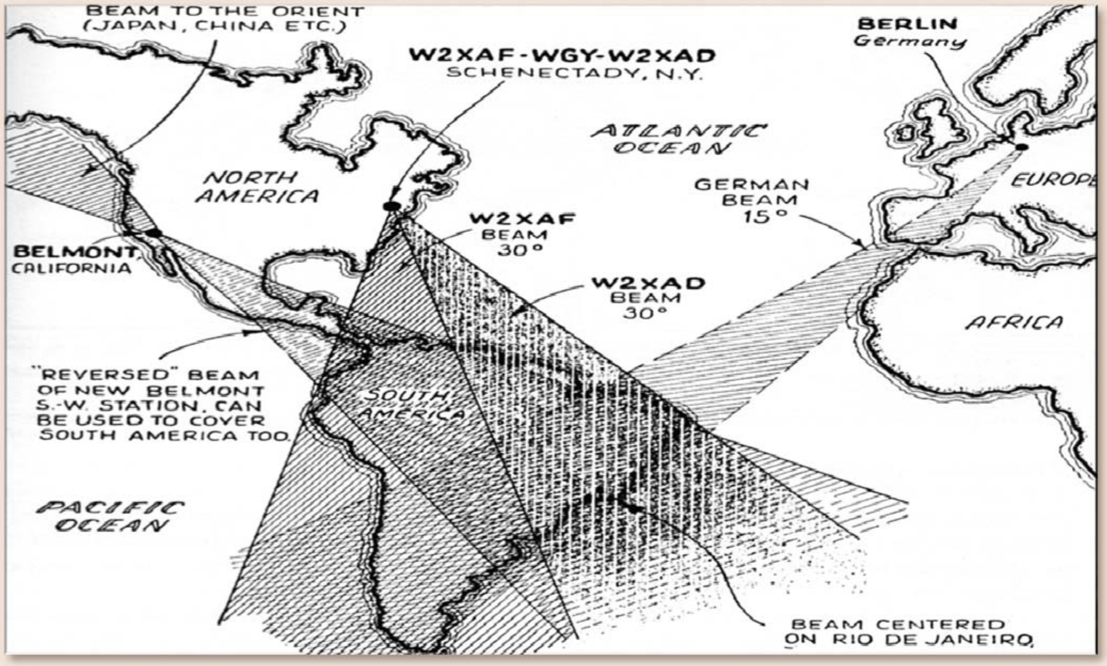
In 1928 WOR operated W2XAQ as a "Remote-Pick-Up" link for use on airplanes and ships. In the early 30's WOR brought up experimental broadcast stations W2XJL and W2XUP on 11 meters. These facilities took part in the experimental facsimile transmissions of the late 1930's. Even Crosley got into the act with its Short-Wave facility at Mason Ohio.

By the end of the 1930's there were 117 affiliates in the NBC South American Network; CBS had 76; and Crosley had 24. Savvy American broadcasters also used the Short-Wave signal as a backup at their domestic affiliates, in the event of Long Lines transmission interruptions.

During World War Two the U.S. government moved to acquire transmission facilities in support of its new "Voice Of America." At first VOA program time was leased from broadcasters but eventually the government seized 14 transmitters, reimbursing the operating costs for the duration. This was no great hardship for the Short-Wave broadcasters; they had been viewing the cost of operations as no longer worth the investment. (CBS was an early exception to this view; late to the game, they were reluctant to relinquish an as-yet-unproven distribution effort.)

At the request of the Office Of War Information, NBC and CBS began to bring up Short-Wave transmission plants along the Left Coast; among them the beloved KWID. The U.S. Government paid for a 100 kilowatt transmitter at the antenna site of KSFO and it went on the air in summer 1942. KWID's purpose was to cover the Pacific Region, as similar transmitters were doing for the Atlantic region, from the other coast. During World War Two, KWID touched the hearts of servicemen and women across the Pacific Theater.

Here's a view of some of the coverage of South America:



Original photo source unknown

After the war the Short-wave stations were returned to their owners but, by then, broadcasters had lost interest in International broadcasting and were happy to leave the government in charge. NBC and CBS provided government programming under contract until 1948, then left Short-wave broadcasting entirely.

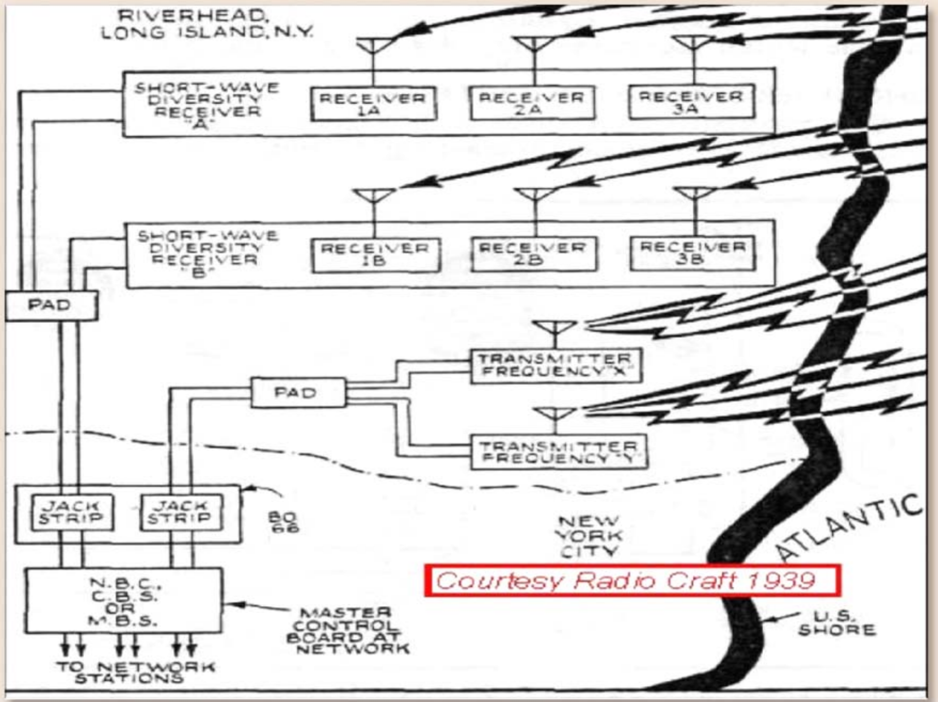
Domestic Short-Wave "broadcasting" diminished under the solid footprint of the Medium-Wave band. Most stations turned in their Short-Wave licenses. That left but a small handful of American-based International broadcasters and the mighty Voice of America.

Short-Wave Feeder Services

Short-Wave was however important in the 1930's as a result of the unrest in Europe and elsewhere. On the in-bound side, Short-Wave links were the only way to import live coverage from abroad.

In the U.S. the East Coast International facilities were well-matured (major West Coast landing-sites had yet to be developed). RCA Communications had redundant speech links to Europe that operated in the 50 to 70 meter band. The relatively reliable circuits helped reinvent radio news. Listeners gained an ear into International developments from Europe that enabled a new genre of radio journalists; CBS's Edward R. Murrow and NBC's Max Jordan principal among them. Broadcasts from the Pacific were harder to accomplish but were no less dramatic or impactful.

Now a redundancy diagram of the receive side of European Short-Wave transmission:



RadioCraft wrote this story: *"Behind the scenes of the Trans-Atlantic hook up:* Point to point communication was given one of its severest tests during the Czechoslovakian crisis (of 1938). In three weeks NBC delivered 110 International broadcasts, CBS made 98 foreign pickups, while Mutual, which made its coverage by playbacks of recorded foreign news broadcasts, contributed five European broadcasts – altogether a total of 213 completed and broadcast foreign programs. National differences were forgotten that the public might be served." *RadioCraft, October 1939*

All of which takes us back to stories about how the networks used their distribution systems, and about how AT&T acted as a benevolent traffic cop in keeping it all moving while continuing its march toward 'network perfection' and a ringing cash register.

In the final section we'll look at program-transmission specifications, operating-level and noise definitions and the development of the "Carrier" and the VU meter.

CHAPTER SEVEN

AT&T Operations Center   *Western Electric "Oscillator"*

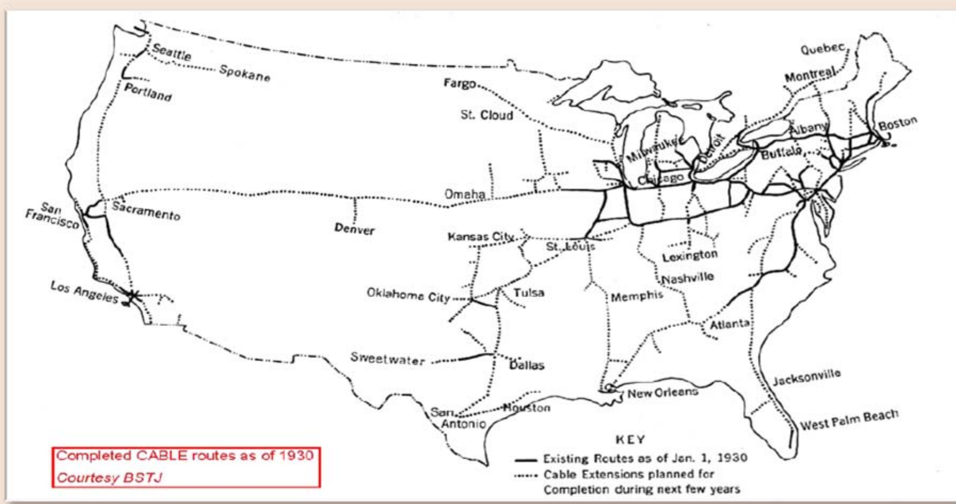
In this final chapter we bring it all together to review the practices and methodology in use as the wire networks were matured.

Our timeline ends in the 1940's. To be sure, there were many important developments over the decades following, as radio network transmission architecture moved into microwave links, satellite distribution and of course digital by fiber optics. There's much to be told in that regard but we need to end somewhere, and so we'll conclude this first timeline by collating the cumulative knowledge and practices of wire network operation into the 40's. In this section we visit the Long Lines wire offices ("Toll Boards") and the network distribution centers. Early photos will continue to do much of the work. We'll also review transmission-system standards.

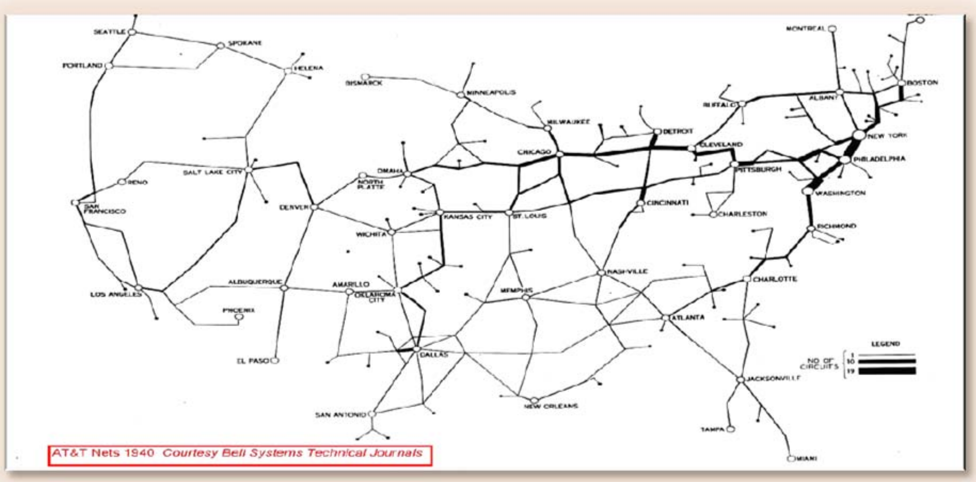
By 1930 the practice of "stealing and ganging" telephone channels for wide-band service had been abandoned; long-distance telephone traffic was too demanding and new construction from the late 1920's onward included parallel program-circuit architecture. As to the voice/program backbone itself, Radio News reported: "By 1938 there were 4 separate transmission routes from the Mississippi to the West Coast. The *Northern* route was Minneapolis/Fargo to Billings/Spokane/Seattle.

The *Central* trunk ran Omaha/Denver/Salt Lake City/San Francisco. A "*Near-South*" path was Oklahoma City/Amarillo/Albuquerque/Whitewater CA. The "*Real-South*" line was routed Dallas/El Paso/Tucson/Yuma/Los Angeles. North- and South-running trunks inter-connected these cities as needed. (Ad-hoc program) channels were pulled down after each segment's "Goodnight" and run up for testing. The next morning service started all over again."
Radio News magazine, July 1938

In the 1930's everything *east* of the Mississippi was in cable (both buried and elevated). Cable design included separated, heavier-gauge pairs dedicated to program transmission; these pairs were isolated from the message-traffic wire bundles, as we noted earlier.



Completed CABLE routes as of 1930
Courtesy BSTJ



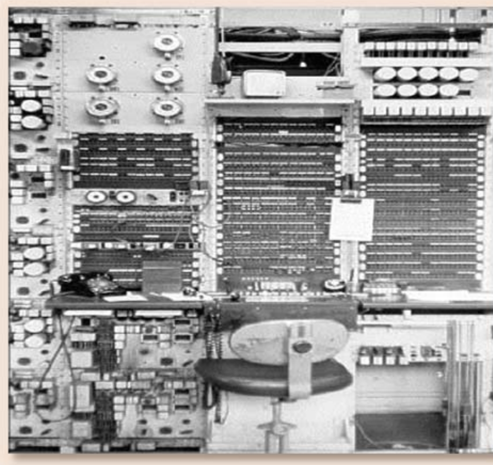
AT&T Nets 1940 *Courtesy Bell Systems Technical Journals*

By 1940 the cable build-out was essentially complete and open-wire was relegated to use by customers along the rights-of-way (primarily the railroads).

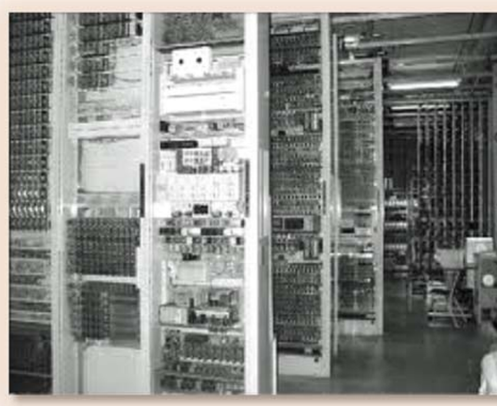
Long Lines also divided the country into 4 *operational* areas: Eastern (New York in control); Northern (Chicago); Southern (Cincinnati) and Western (San Francisco). “43,000 miles of Order Wires and telegraph circuits were dedicated to ‘Command, Control and Coordination.’ Each of the four centers is connected to every repeater station in its territory.” *Bell Systems Tech Journal*

Long Lines Program Specifications

At the Toll Boards across the country, additional agility made it easier to handle ad-hoc program requirements. Huge rooms full of telephone-size racks stretched endlessly across the room; each component of each rack firmly installed using standard installation practices; all equipment hard-wired to patch bays and “Christmas-tree” wire distribution frames.



Repeat coils stood by for use in balancing and matching difficult circuits.



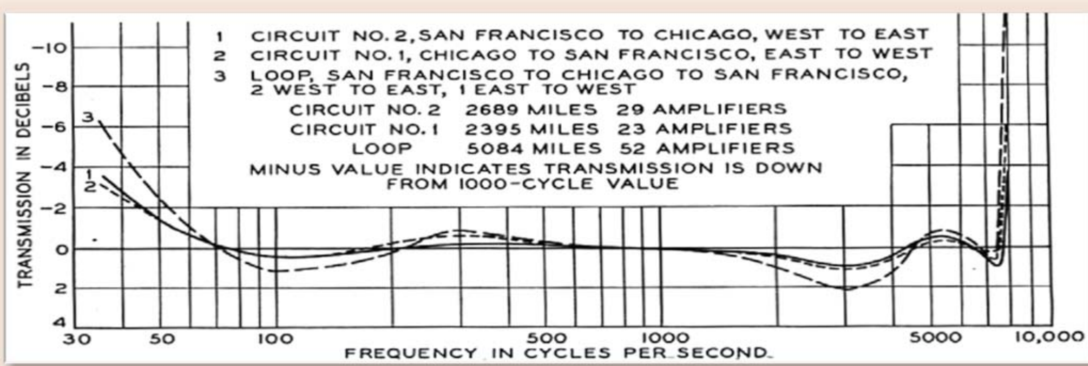
Heat load was a significant factor; the bigger offices had thousands of tubes in operation. It was important to predictable wire performance to keep temperatures constant.

The offices themselves were physically protected against man-made and natural storms; partly underground or within reinforced buildings above ground and within reach of protected power. Hundreds of thousands of underground cable pairs were each terminated and conditioned. Huge battery rooms provided floating power.

Photos courtesy Cedar Knoll Telephone

Within the wire offices program-transmission was a separated segment, operated by qualified technicians trained to know the difference between "message" circuits and "toll audio." Specialized measuring equipment with different weighting characteristics was put into service as explained below.

A standard combination of shelving amplifier and equalizer was now in use at the repeater stations. Engineers learned early on to use a form of "distribution amplifier" on line taps, so a short in the tap leg to a local station didn't affect the main circuit path. End-to-end radio network circuit response was a guaranteed 100 to 5000 cps (though some links measured 50-8,000 cps). At repeater stations, a minimum of 30db cross-talk separation was maintained between incoming and outbound circuits (protection against 'ringing').



Bell Systems Technical Journal

The Standardized "Specs"

By 1930 engineers were getting a handle on dynamic range. They had previously established a *maximum* transmit level of +2 db over "0" ("0" still TBD) and the *minimum* satisfactory level which was the point at which cross-talk was heard. That range was 27-30 db. To maintain good noise performance across the network it was standard practice for the engineer in the network's distribution head-end to be in contact with engineers along the line. Operators monitored volume levels and coordination obviated the potential *smash* that might occur at the end of the line, if engineers at every repeater added a few db of gain…all at the same time.

Some of the more important Long Lines specifications now being developed:

> Operating Level

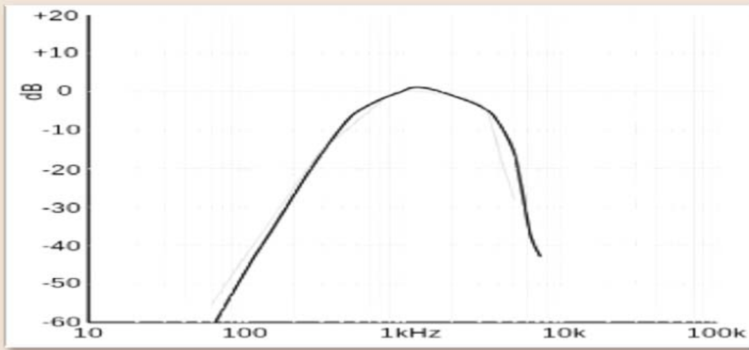
Because of differing measurement methodologies, there had been no standard reference level across the telephony universe. Reference and calibration levels were plant-dependent, ranging from a measured 1 mw in 600 ohms to as much as 12.5 mw in 600 ohms (or 500 ohms as the case might be). Early on, an amplifier-driven direct-current milliammeter was the 'meter standard' and little attention was given ballistics. Variations of this meter were tried; some peak-reading and some RMS. Some were lightly damped; others more heavily. A "mid-scale" meter reading represented the standard level and actual levels were calculated by observing *the position of the input attenuator that brought the meter to mid-scale*. This "reference level" was initially subjective; sometimes defined as being "10 db below the point at which distortion was heard." *Bell Systems Practices*

> Noise Reference

The noise reference level was established as 90 db below 1 milliwatt of power in 600 ohms. (This baseline noise level matched the ideal 90 db-loss "cross-talk coupling" figure.) Actual noise was then measured as a number ABOVE this optimum level. This measurement was called the "**dbrn**" (**db** **r**eferenced to **n**inety). So -60 dbm in the audio world was "30 dbrn." Extracted from the *dbrn* was the "***dbx***"(the cross-talk measurement above the reference). Another measurement figure in use was the "***cu***" or "crosstalk unit."

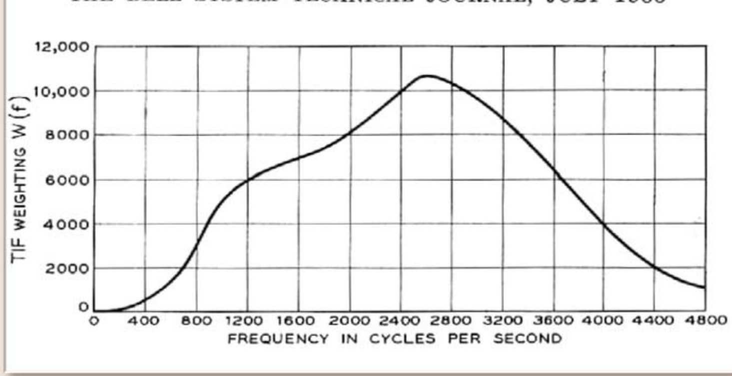
> Weighting

It was impractical to measure realistic noise in a transmission medium unless the band-pass of the audio channel was defined. This was done electrically by adding a "weighting" network to the measuring device. The weighting network would pass only the frequency range of interest.



“C-message” weighting for voice traffic *Wikipedia*

Weighting was also employed in the introduction of the “Telephone interference Factor” (“TIF”), and a “TIF Meter” was developed to compare measured interference voltages in the speech band. The meter recognized the harmonic content of interfering noise. As noted by the date below, this measurement survived into the modern age.


THE BELL SYSTEM TECHNICAL JOURNAL, JULY 1960

TIF weighting *Bell Systems Technical Journal*

> Wire Standards

The long-distance cable universe was now 16-gauge twisted pair with a capacitance of 0.062 mfd/mile. These circuits were loaded with 22-mhy loading coils about every 3000 cable feet. With this conditioning, the loss per mile was about 0.25 db through the speech pass-band.

Phantoming of these loaded circuits was not practical; real-world reactances upset longitudinal balance. The pairs dedicated to radio program service were carefully placed within the cable. *From the Bell Systems Technical Journal*

> Group Delay

For the first time, "Group-delay" performance was considered in the context of the overall wire network. Total high-frequency delay of about 1 ms and low-end delay of 75 ms (from the coils) was acceptable on an end-to-end circuit.

Most of these specifications were derived from objective measurements. Developers weren't opposed to subjective evaluation either, as was the case when the TIF curve above was established (TIF standards were compared to listening tests).

The VU Meter: A Tool for Dynamic Measurement

In January 1938 engineers from the radio industry sat down with Bell Labs to resolve the ongoing issue of operating-level definition and to define a standard measurement methodology. From the 1920's "Transmission Units" ("TU") were used to describe operating levels. A "TU" was based on log derivations and closely resembled a db. 40 TU was a power gain of 10,000.

In 1939 a new "Volume Indicator" ("Volume Unit" or "VU" meter) replaced the TU meter. There was a lot of discussion among engineers as to whether the meter should read peak or RMS values. Substantive group-listening tests were conducted to determine the meter's relative indication of 'apparent loudness' as well as its reflection of practical operating voltages in a complex waveform.

The final compromise was a 'quasi-RMS' approach…even though it was found that this meter couldn't quantify the imbalance between speech and music. (Your author has seen a letter between a writer of NBC's "Fibber McGee and Molly Show" and its ad agency, in which the "music too loud" complaint is voiced.)

Attention then turned to full-scale response time. The meter was to provide a less-than-critically-damped movement such that, with a 1,000 cps sine wave applied, the meter would read 99 percent in 0.3 seconds, with a 1-percent over-swing.

The final meter version was to be illuminated and driven by a full-wave rectifier. A series resistance of 3900 ohms was specified for a '0' dbm = '0' VU" reference. The overall impedance of the new VU meter ended up at about 7500 ohms.

The meters read either in db ("A" Scale) or a corresponding voltage-percent ("B" Scale). The meter size and scale was expanded; they even specified a color for the meter wallpaper. Then…finally…the standard reference level was re-established. "0" VU was firmly defined as "1 milliwatt in 600 ohms."

Designers also acknowledged that the VU meter added about 0.3% harmonic distortion. (In the past few decades, purists have recognized the distortions introduced by the meter, and have learned to buffer the meter.)

With the VU meter in place at networks, radio stations and wire offices, it was finally possible to establish and maintain uniform levels. Some Long Lines offices came up with an ingenious trick in which a single shared VU meter was displayed via a projector/mirror so that the meter might be seen from wherever the technician was adjusting levels.

The Weston Company, which had participated in the standards-setting, introduced the "Weston VU Meter."   It immediately became the industry standard. Here's the "B-Scale" type:

Extended Network Frequency Response

AT&T knew that "ideal" circuits could be made to pass 20-20,000 cps with decent dynamic range. The pragmatists however reminded the idealists that such performance wasn't worth the cost: the weakest link in a radio network was the AM radio broadcasting system and its receivers. As a result of this reality check, when transmission-circuit redesign was undertaken, the new wire circuits were qualified to pass 50-8,000 cps +/- 1 db, with about 40 db dynamic range. Until the demands of FM, it made little sense to expend time and dollars to exceed these specifications.

Radio Craft wrote a story in 1934 on what might be expected in the future: "For special occasions transmissions (over the telephone lines) are being made over a band of 15,000 cycles. And short-distance demonstrations have been given of cable transmission over a frequency band of 45,000 cycles." *"Third Dimension in Music," Radio Craft, May 1934*

Multi-channel Audio Circuits

Pragmatic benchmarks notwithstanding, by the 1940's Bell Labs was doing psychoacoustic work to determine acceptable frequency-response limits for human hearing with an eye toward extending the response of the wire plant. FM broadcasting was about to be a reality.

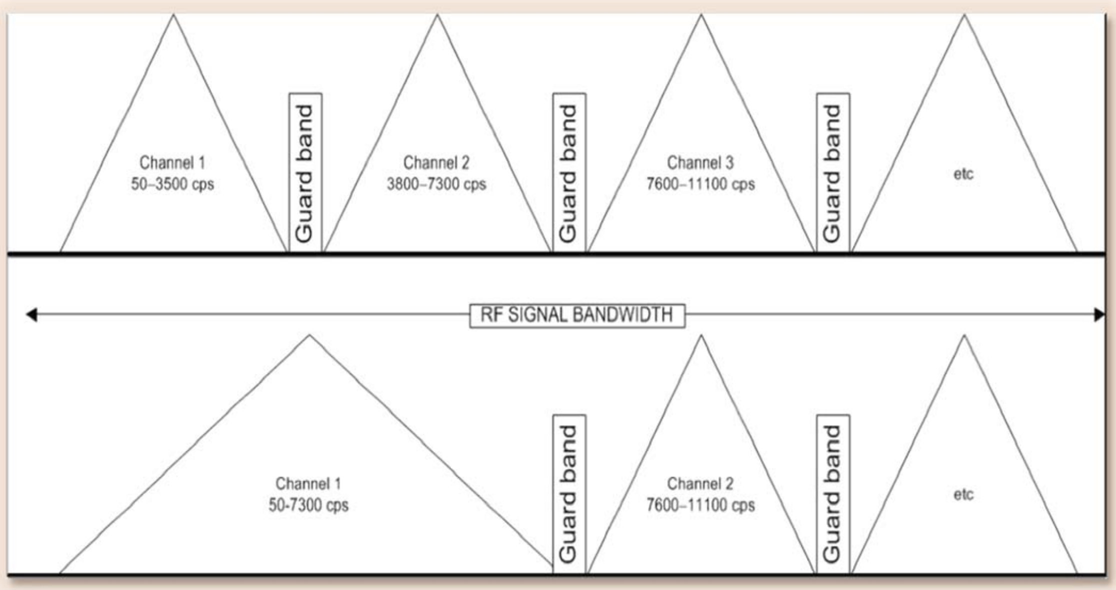
The FCC had also experimented with double-wide "high-fidelity" AM stations in the 1500+ kc band, as well as with APEX. "**APEX** was an experimental radio broadcasting system introduced in the United States in 1934 that used high frequencies between roughly 25 and 42 mcps and wideband AM modulation (as opposed to traditional AM broadcasting's narrowband modulation) to achieve high fidelity sound with less static and distortion than Medium-Wave AM stations in the so-called Standard Broadcast band. They were called "apex", "skyscraper" or "pinnacle" stations because of the height of the broadcast antennas used." *Wikipedia*

A number of APEX stations came on the air; none survived. To address FM, APEX and other high-fidelity opportunities, Long Lines proposed a service that delivered 30 to 15,000 cps. This wide-band performance required the use of "**Carrier**" for audio transport of consistent quality.

Carrier: Bedrock of the Future

A "Carrier" system was a group of combined RF signals, each carrying an audio channel. Together they formed a very-wide signal placed on a wide-band telephone channel. This composite signal accommodated several telephone channels, stacked "side-by-side" if you will, and kept apart by the use of filters specific to each channel to be transported. If you wanted to carry three channels of telephone audio (3,500 cps high-end) you would use three RF signals on three frequencies, with 'guard bands' between channels. If you wanted to deliver wider audio response you could throw out some of those channels and transmit fewer (but wider) RF signals.

Here is a ***conceptual*** *drawing*…this is not quite how it works but you may get the idea. The upper group is carrying 3 (or more) 3500 cps-wide telephone channels; the lower configuration drops two of the telephone channels for one wider-band program channel:



The RF that transported the audios was "**S**ingle-**S**ide-**B**and-**S**uppressed **C**arrier" (SSBSC) at a frequency well above the normal audio pass-band of the wire (centered at first, for example around 40 to 50 kilocycles). The Carrier system presented as a four-wire terminal. A cool feature was an imbedded control signal to reverse the channel direction as needed.

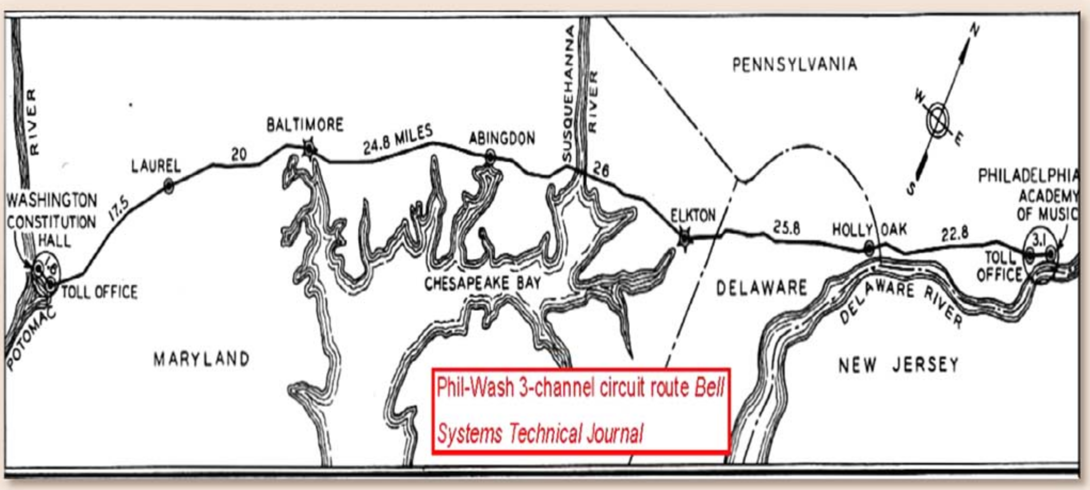
Pre-emphasis was employed and "Modem" delay correction and equalization added. "Drop" to a local customer was accomplished by band-filtering the chosen "sub" carrier and adding de-emphasis to the selected channel demodulator. A telegraph circuit could be superimposed on the circuit paths. All of this in the analog domain.

A Carrier circuit required a two-way pair of wide-bandwidth transport channels. By the 1930's some wire lines had enough bandwidth to handle a Carrier that transported 4 telephone channels. By 1949 twelve-channel systems were operating. Demodulation and reconstruction was of the lower side-bands. Again, the Carrier system was capable of 15,000 cps demodulated audio if some voice channels were removed and others "stacked."

Carrier was a break-through in message capacity. Before the digital age and its mux-ing, Carrier technology was about the last frontier. With the introduction of wideband coaxial and radio links, the capacity of Carriers was continually expanded. But that story belongs to the more-recent telephone company and is beyond the scope of our review.

Leopold Stokowski and the Grand Experiment

Because most successful engineers are experimenters at heart, in 1933 Bell Labs launched a project to demonstrate multi-channel audio via Carrier between Philadelphia and Washington. The SSBSC placed on the cable was at 40 kcps. (The frequency was generated by doubling a 20 kcps audio generator and sending the original 20 kcps along as a reference pilot.)



Phil-Wash 3-channel circuit route *Bell Systems Technical Journal*

There were repeaters about every 25 miles along the 150-mile path.

The Philadelphia-Washington demonstration required three audio channels. Selected cable pairs were un-loaded and additional repeaters of the new, “negative-feedback” type were used. Suppression of metallic circuit noise and longitudinal interference was necessary on cable pairs selected for the demonstration *as well as on adjacent pairs*. As they fine-tuned the channels, they encountered and removed several interesting roadblocks. (For example, engineers found noise in the circuits being induced by pair-coupling in the Baltimore wire office. They dealt with it by the addition of longitudinal chokes in the lines.)

The response of the derived audio channels was to be 40 to 15,000 cps within a db or so, with 65 db useful signal-to-noise. *From Bell Systems Technical Journal*

The difficulty in filtering in the neighborhood of the SSBSC signal led engineers to adopt Vestigial Sideband modulation. This resulted in increased stability and audio response down to DC (though engineers felt 40 cps was a pragmatic high-pass cut-off). Carriers had to be synchronized because of the Vestigial modulation employed. (They also tested pre-emphasis on the path but decided not to use it in the actual demo.)

Since you’ve made it this far…how about some *serious* detail?

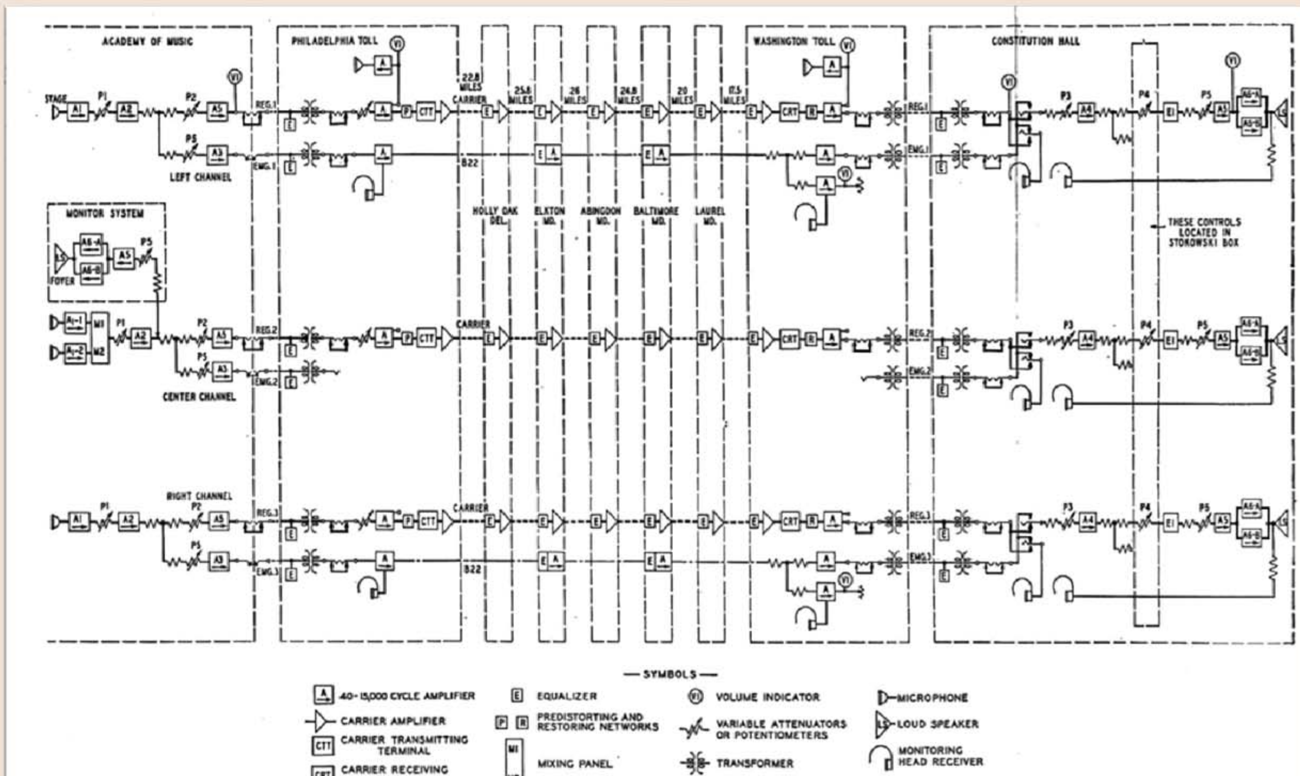


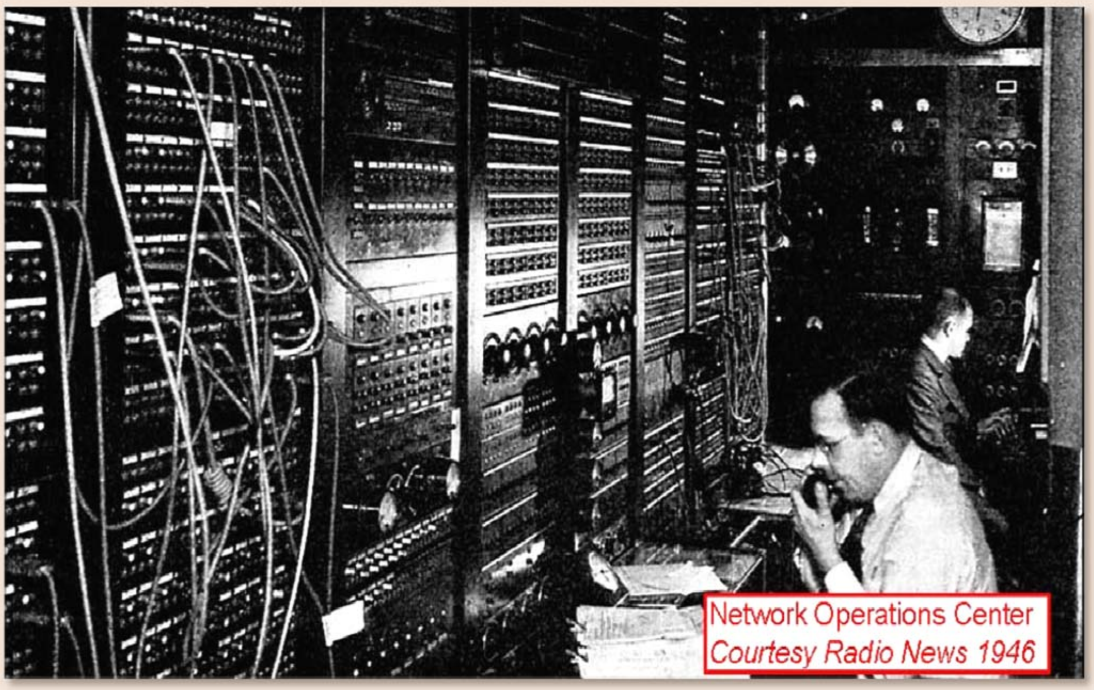
Fig. 10—Schematic diagram of circuit layout for 15-kc channel used for symphonic program demonstration.

Bell Systems Technical Journals

The three channels were ready on April 27, 1933. The Philadelphia Orchestra was to play a "test concert" at the Philadelphia Academy of Music. The band was miked Left-Center-Right (a fourth "soloist" mike was mixed into the Center channel as needed). Three loudspeakers were placed in Constitution Hall in Washington, in positions complementary to Philadelphia's microphone placement. At Constitution Hall, measurements were made at some distance into the audience space, and final equalization was used to help the high-end audio reach that test location. The "Conductor" at the Washington receive end (Leopold Stokowski) was also given a bass boost/cut control, shelving at 500 cps. Finally…a talk-back circuit and a click-track was provided. The Bell Labs' Harvey Fletcher was part of the experiment. The BBC again: http://www.durenberger.com/fletcher3channels.mp3

By all accounts, the demonstration went extremely well. What fun to have been there!

Switching at the Radio Networks



Network Operations Center
Courtesy Radio News 1946

Network control rooms were full of routing switches, patch-bays, relays and meters, staffed by a bevy of tie-clad nail-biting engineers armed with program-routing schedules and tasked with watching operating levels. Out of New York, NBC's Master Control fed Red, Blue, WJZ, WEAF and W3XAL as well as ad-hoc and regional networks along the Eastern seaboard. It could be a scheduler's nightmare.

The "Chimes" as a switching cue

"Programs on the Red and Blue networks often ended at different times. NBC protocol was that the program finishing *first* relinquished control to the later-ending-program's announcer. That worthy would switch the first-vacated channel (whose show was over) to simulcast the show not yet ended. The 'last' announcer then sounded the chime for *both* networks and released the temporarily-piggybacked second network for its own follow-on programs."
Proceedings of the Radio Club of America, October 1930

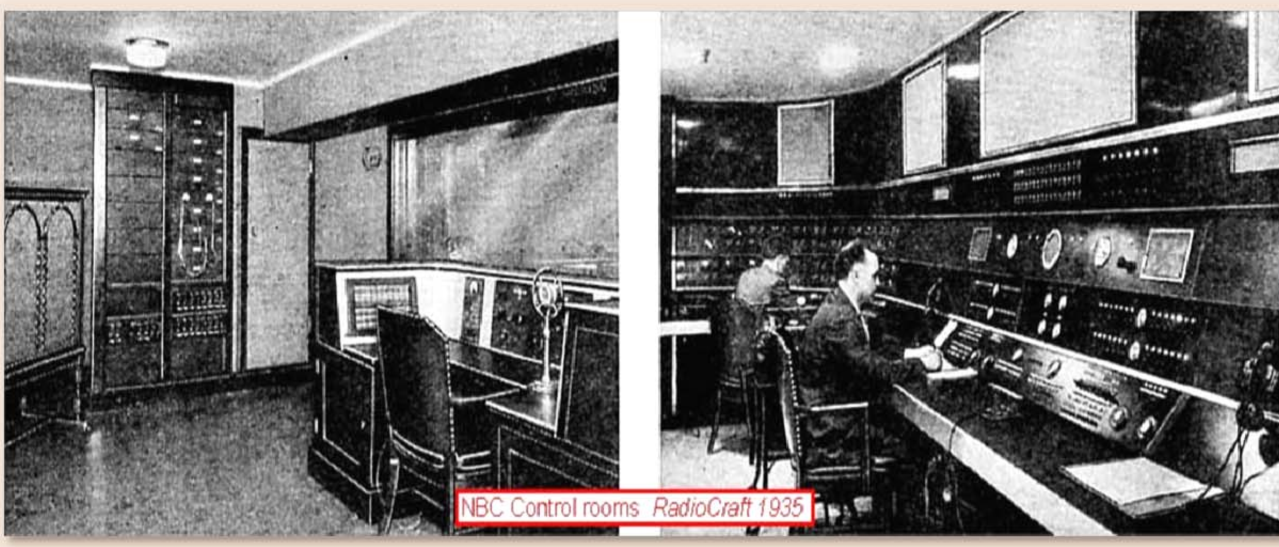
It was felt that "the best coordination of thought and action is obtained by having the announcer do his own switching." *NBC Files*

The announcer also "rang" the (then-manual) chimes for national network cues. (Stations that operated regional and split networks used their own chimes for their own signaling.) Here's a clip of a network cue/WEAF station break (the "Announcer's Delight" control panel can be seen at left): https://www.youtube.com/watch?v=96rA-QgXL58

The "Rangertone" NBC chime machine replaced the manual chimes in 1930. The chime machine permitted automatic cutoff of late programs, made the chime-sound consistent…and took the end cue away from the studio announcer. Here's a delightful adaptation of the chimes in a song titled "I Love You." http://www.durenberger.com/nbciloveyou.mp3

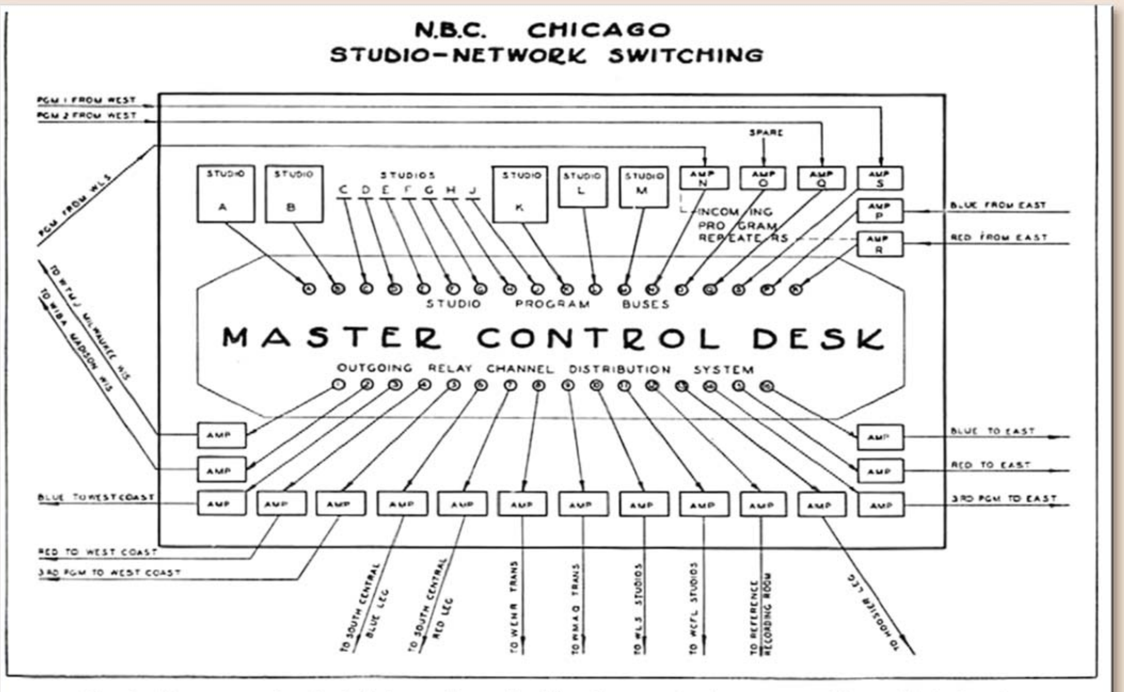
(And by the bye, if you want more on NBC Chimes history, we can point you to the great web-site http://www.nbcchimes.info/linkcred.php

Views of NBC Control rooms (left is an early studio operation; right is network distribution):


NBC Control rooms *RadioCraft 1935*

Chicago's switching hub played the key role in NBC distribution. "All NBC passed through Chicago; here was located NBC's main network center. 152 amplifiers. 3,160 jacks. 976 relays in the circuit." *Radio News, March 1928* What a maintenance nightmare! But a good practical location for a network that was time-shifting and routing its programs all over the country.

NBC Chicago Switching
Courtesy Radio News 1938



Block diagram of what takes place inside the control room radio switch track.

CBS did all its switching from New York, with the exception of some shows routed out of Hollywood. ***We're searching for definitive descriptions of CBS's and Mutual's switching and routing practices. If you're aware of such detail, we'd appreciate hearing about it!***

Network Switching at Long Lines

As to AT&T's role in network switching, we once again open the Bell Systems Technical Journal: "Special operation and special switching and reversing equipment are required at many points along the network. Much of this equipment is under remote control from selected points. The greater portion of the switching of program circuits is done at about 25 points throughout the country on the major networks. On the average more than 25,000 switching operations per month are performed at these 25 points. During the busy hours of any typical evening there may be something over 500 men on duty at all of the offices about the networks.

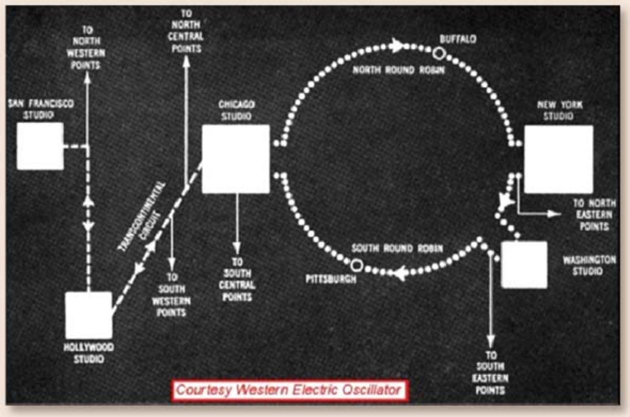
"At points where switching requirements are simple, the switching equipment consists merely of a few keys. At the larger points where the switching requirements are complex, the switching equipment consists of elaborate relay and control arrangements. These are so designed that it is possible to set up in advance the circuit combinations required for the ensuing program period without disturbing the programs in progress.

"The actual switching operation takes place at the instant the monitoring attendants signal the receipt of the last of selected cues, and not before then. This type of arrangement affords a maximum of protection against error, as it is possible to check the presetting for the next switch or make a last minute change if necessary any time before the switch has been made. Transmission is monitored continuously at strategic points about the networks. In order to facilitate the activities of this group many thousands of miles of intercommunicating telephone and telegraph circuits are provided full time for their use." *Bell Systems Technical Journal*

Typical AT&T network switch center (Washington) *Bell Systems Technical Journal*

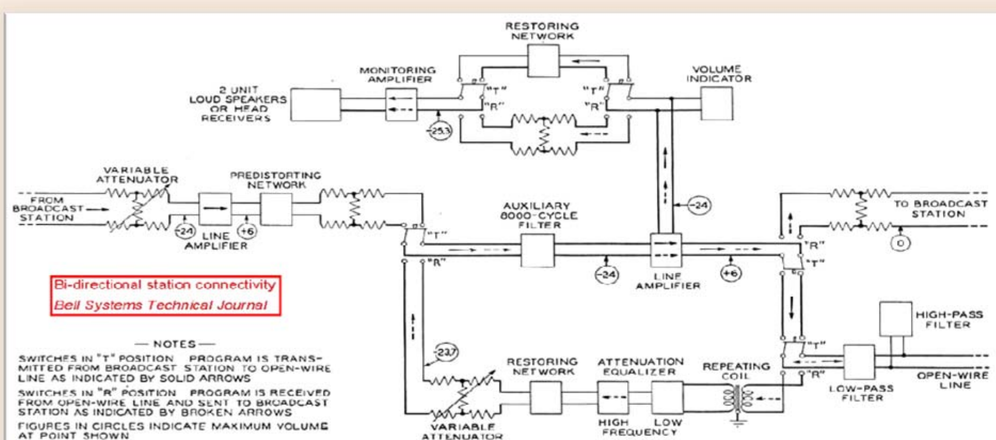
The Round-Robin

Boston Historian Donna Halper recalls that NBC fed its eastern stations in a "round robin" manner as far back as the late-30s. “This was a loop that went from NYC, perhaps to Boston, then through Cleveland, Chicago, St. Louis, etc., the South, Washington and back to NYC. Major points could break the loop and insert audio. It was "interesting" when the originating station didn't break the loop for enough time for audio to die out before closing it.”



This arrangement employed a form of “Drop-and-Insert” topology. It was also the technique used by a group of “1-A” stations when operating “Clear-Channel Round Robins” with participation from talent at each station, being fed to all other stations. It took some savvy about “mix-minus” on the part of broadcasters…and they didn’t always get it. “Mix-minus” was an unusual way for radio guys to think back then.

By the 1940’s mature, standardized network arrangements had survived the test of time and the demands for program transmission. Here’s a matured AT&T/affiliate interconnect:



Well now, we're fixing to go away. We've reached the end of our look at AT&T Long Lines through the 1940's. **Now it's your turn.** Your garrulous author anticipates publishing follow-ups, revisions and corrections on the web-site and we welcome your input.

Before we go, as an unrequested 'encore' we offer a few anecdotal "snapshots:"

SNAPSHOT 1: "ABC"

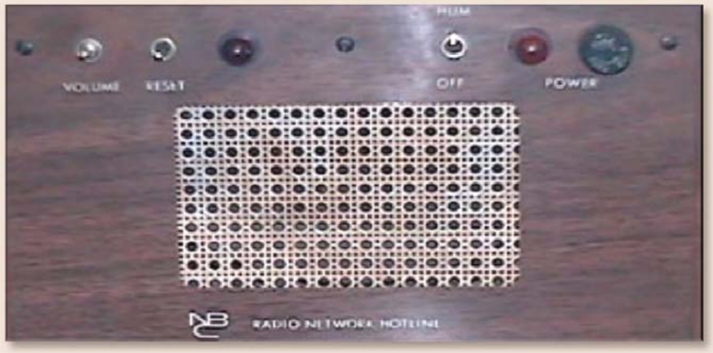
Jim Ramsburg did some fascinating research on when the "real" ABC finally came into being as a national network: "…when Edward Noble's American Broadcasting *System*, Inc., bought the Blue network from RCA in October, 1943…he had every intention of renaming his property "The American Broadcasting Company" and re-branding Blue's on-air identity as ABC.

"But there was a hitch in his plan because the name ABC was already registered to Detroit broadcaster George B. Storer, who had created his own American Broadcasting Company radio network in October, 1934. By coincidence, (or more probably not), the original ABC came into being just a few weeks in 1934 after another Detroit station owner, George Trendle of WXYZ, joined forces with WOR/New York, WGN/Chicago and WLW/Cincinnati to establish the Liberty Network which morphed into the Mutual Broadcasting System…Lack of programming and advertising doomed the original ABC within a year, but Storer kept the name. So, when Noble came calling the crafty broadcaster knew that he had a seller's market. For that matter, so did the owners of the defunct American (FM) Network, the newly formed and quickly failed Associated Broadcasting Company, the Arizona Broadcasting Company - and the list went on.

"Although Noble's corporate name was changed to The American Broadcasting Company in September, 1944, the chain's on-air identification had to remain "The Blue Network," until all claimants to "ABC" were satisfied or dismissed. But the determined Noble's negotiators worked through the tangle with checkbooks in hands and on June 15, 1945, his network's announcers were finally cleared to read the system cue, "This is ABC…The American Broadcasting Company." *From Jim Ramsburg's Gold Time Radio* http://www.jimramsburg.com/

SNAPSHOT 2: NBC's "HOTLINE"

NBC debuted its "Hot-Line" network-alert sometime in the 1950's (date uncertain). From my recollection of the system, the alert signal may have been a low-frequency tone (60 hz?) sent on top of the network audio to a tuned receive system at the affiliates. *Photo courtesy dcrtv.com:* ***Perhaps readers can add information on the protocol.***



NBC "Hotline"

SNAPSHOT 3: CBS "NET-ALERT"

In a 1960 BROADCASTING Magazine story, CBS announced a new system for alerting its affiliates…christened "Net-Alert." The original system, deployed around 1961, used a series of two-frequency pulses of around 30 milliseconds that rode on the network audio.

Courtesy RCA Journal

CBS Labs carried out a good deal of subjective analysis on pulse-duration, since the pulse had to be reliable yet not audibly objectionable. Pulse level was to be 20 db below program level. The number of pulses sent determined the alert level and a stepper relay at the affiliate receivers could be heard stepping its way up to as far as Alert # 9—"National Emergency."

I can recall being in the WCCO Control Room on some of the few occasions when the "non-routine" sequences were firing…you'd count the relay clicks and chirps and as the count got higher you'd go from "*what's happening*?" to "**Oh-Oh**." The system was upgraded in 1978. Here's the Radio Club of America's explanation of the early system: http://www.durenberger.com/documents/netalert.pdf

SNAPSHOT 4: ABC x 4

What shouldn't have been an original idea was fielded by ABC in 1967. The plan was to use the "quiet" portion of each hour to feed additional programming, enabling additional affiliates.

Out of that idea came the American Information / Entertainment / Contemporary / FM Radio Networks; all on the same pair of wires.

SNAPSHOT 5: "HARDENING" STATIONS

In 1942, at the height of World War Two, AT&T had opened the first cross-continent *cable* line. It was more secure than open-wire and prompted NBC to propose the establishment of an ad-hoc "Defense Network" to join literally all of the 880 stations on the air for national defense emergency news. The effort was to include "hardening" of individual stations; particularly with respect to power supply. Intriguingly, in the proposal NBC disclosed its deployment of a new "RCA Alert Receiver" that worked on sub-audible tones from key AM stations. *From Radio News, January 1942* (The hardening concept has been recently re-implemented in today's broadcast infrastructure.)

CODA

For those of you who never knew the sound of radio programming over a long pair of wires, I hope this information has been of some interest. **I strongly value the attribute of *CURIOSITY* and I applaud you for making it through this history!**

Most of us older folks are conversant with what happened to network radio transmissions once we entered the satellite age. (And by the way…*that* transition was by no means seamless.) By the satellite age of course, Long Lines was trunking its audio and video on carrier, on wide-bandwidth radios; breaking at demark points to feed individual stations and other customers via local copper drops. Fiber was on the horizon, thanks to an Atlanta engineer named Snelling.

There's an App for that

Today we are accustomed to breaking down knowledge barriers and solving problems in the time it takes to write or buy some good code. This happens because the world has become a binary place. It took a disproportionate amount of analog processing power to finesse the analog world. That "processing power" was the capability and the experience of the AT&T engineers and technicians who wrestled to understand and subdue each and every variable in their electrical world. That analog world was the hardest of all to conquer, but they did a pretty good job of it. And they left a "standards" legacy. The rack rows, the battery power, underground, inter-office ties, pair "conditioning" can all be found in today's "wire" (fiber) offices. There was no dither in the old phone world; you took everything you could get, noise and all. It's a tribute to telephone companies that they did it so well!

"Everything that once was wireless is now wired. Everything that once was wired is now wireless." *- Rodney E. Nilk*

Your "old-veteran" writer is appreciative of the reliable wire service AT&T Long Lines and the local RBOCs provided. There's obviously more to these stories and we encourage you to add your own two bits' worth or to refer our readers to other resources. At some point we anticipate publishing follow-on work that will take us down other, related paths.

I want to recognize the engagement and support of Richard Hess, who provided invaluable assistance on formatting and publishing of this work. He embodies the principle espoused by my dear late friend Jerry Miller, to whom this work is dedicated. Jerry's dictum: "LEARN---EARN---RETURN." LEARN your craft. EARN your living at it. RETURN to others what you've gained in experience and wisdom.

"**Connecting The Continent**" is my own effort at heeding Jerry's counsel.

I appreciate the fact that a hundred years ago AT&T had the resources to "write the book," developing electrical principles and applications that built the platform on which rides so much of our twenty-first-century communications system. They were also possessed of the determination to promote and defend reliable, quality service.

Methinks monopolies were not always a bad thing…

Respectfully submitted,

Mark Durenberger

Minneapolis, Minnesota, October, 2013

Mark4-at-durenberger-dot-com

For further background and information, go to www.durenberger.com