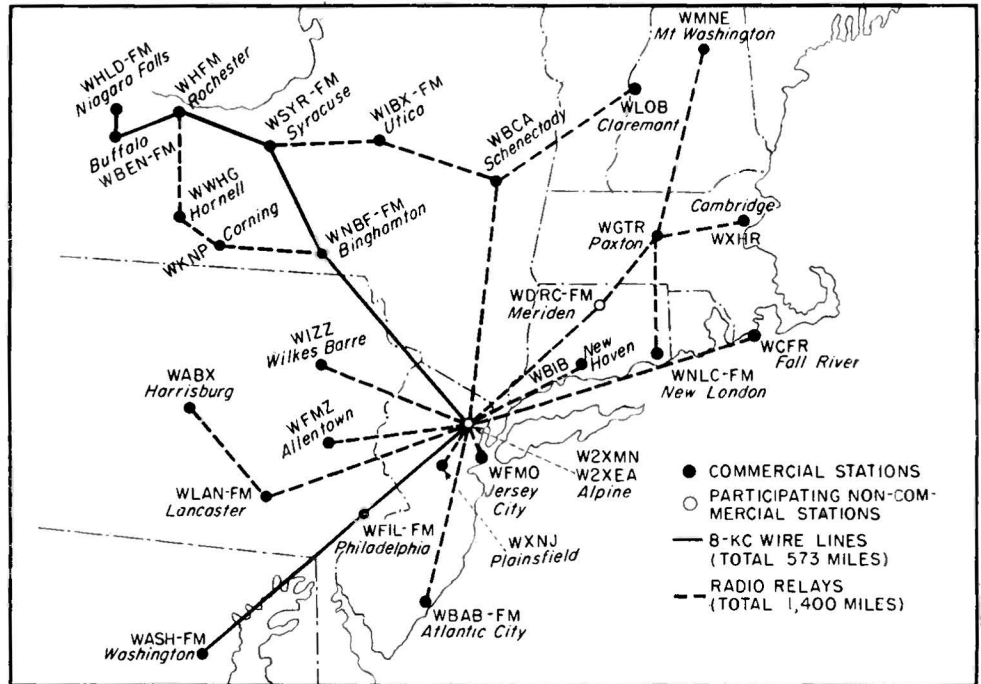


Map of the Continental Network as of Sept. 15; WSBA-FM, York, Pa. has since been added. Wire and f-m relay paths are shown by solid and dashed lines respectively



F-M Chain Broadcasting

Economic salvation for the small f-m broadcaster may lie in the methods of relaying high-fidelity programs from one station to another now used by the Continental Network and others. Techniques employed successfully since 1939 include one that does not require conversion to audio

THERE are many aspects to the problem of f-m broadcast economics, all leading to the important consideration, can f-m pay its way? One important factor is how to utilize a good, and probably expensive, live-talent program on two or more stations, each of which is located in a mutually noncompetitive market area. This is a problem that can not be solved by the vice-president in charge of advertising sales alone, nor by the technical director alone. But both these men know, or should know, that they are treading on neither strange nor dangerous ground when considering the feasibility of chain f-m broadcasting.

A certain elementary book on calculus bears an inscription to the effect that what one fool can learn another can also. Although the f-m pioneers are certainly no more fool-

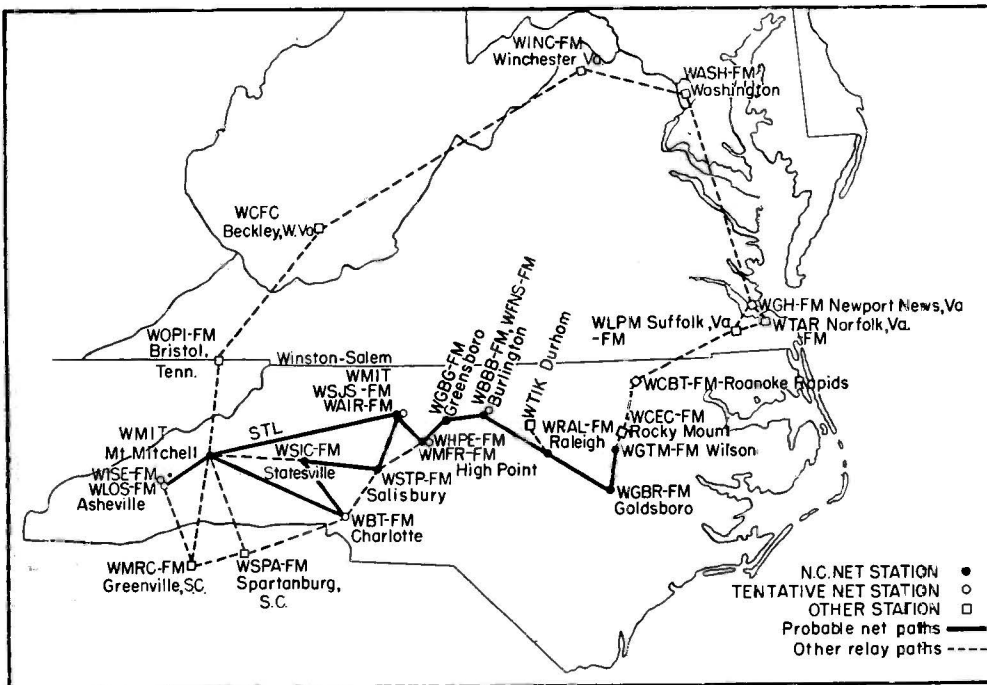
ish than their new and enthusiastic colleagues, the methods by which they achieved success in a relatively uncharted area were less often dry victories of the slide rule than the adoption of Major Armstrong's philosophy,—“Make it work; then find out what makes it work”. New-comers in the f-m field may be heartened by a review of a successful past as well as by an active present. The facts are here.

Original Relay System

The technique of relaying f-m programs from a high-frequency low-power station to a lower-frequency high-power station more suitable for broadcast coverage originated in the early experiments of E. H. Armstrong and C. R. Runyon, Jr., particularly between Yonkers, N. Y. and Alpine, N. J. Aware of

the success of these relays, P. A. deMars, technical director of the Yankee Network, felt secure in planning a three-station network without wires. He had been further encouraged by frequent periods of good reception on Mount Washington, N. H. (37,600 feet below the optical horizon) of Alpine signals on 44.1 megacycles since 1938.

This original commercial relay system comprises a low-power transmitter operating on 156 megacycles (first assigned 133 mc) located on the roof of the Boston studios used to program the a-m and f-m stations of the Yankee Network. The signals from WEOD, Boston, are beamed towards the main 50-kilowatt transmitter WGTR in Paxton, Mass., serving Boston and southern New England, and are picked up there, about 45



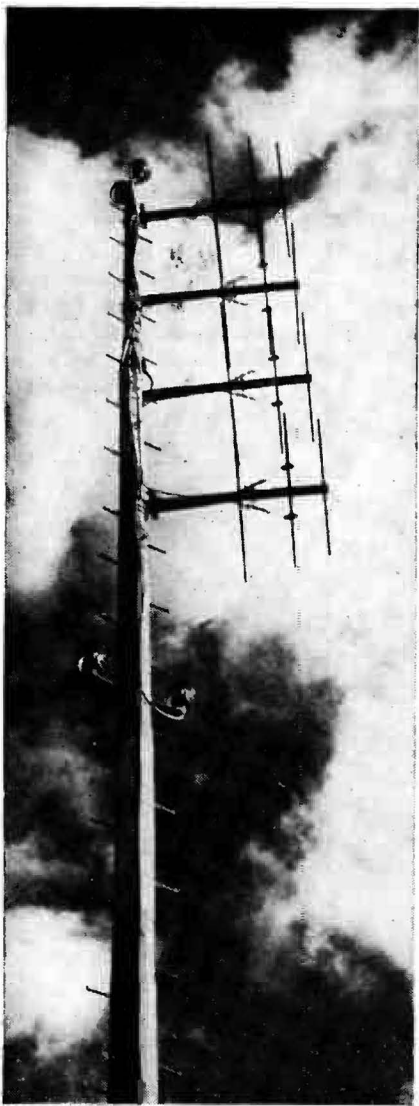
North Carolina demonstration relay net planned for National Radio Week, Oct. 27-Nov. 1. Other possible relay paths are also indicated

Present northeastern terminus of the Yankee and Continental f-m Networks, on Mt. Washington, N. H. The upper bays of the turnstile antenna are used for high-band transmissions

miles away, on a directional receiving array. The program is then broadcast on 44.3 and 99.1 mc and picked up on Mt. Washington, N. H., about 140 miles away, where it is rebroadcast from WMNE, serving northern New England on 45.1 and 100.5 mc. Broadcasts from Paxton started in May, 1939 and from Mount Washington during the winter of 1939-40. Although there have been failures at various points in the circuits the total time off the air has been such an extremely small fraction of the total that it has never been considered necessary even to install local turntables and transcriptions so as to provide local sustaining programs during repairs.

In general, two modulator equipments are provided at each station. The class-C amplifiers following are not overworked and give relatively





Beam antenna for 156 mc atop Yankee Network studios in Boston is used to program Paxton transmitter about 45 miles to west

little trouble. In a few instances, the 50-kw pushpull amplifier at Paxton was operated from several hours up to two days with only one tube filament lighted. Slight retuning of the final was necessary, but the majority of listeners were never aware of the impairment to the signal strength.

Cost Considerations

Time has indeed shown the feasibility of the Yankee Network system, but the original daring conception of the network was predicated on two points. Although it might have been possible to program the Paxton transmitter by a wire line, such facilities were not then available. The best offer that the telephone company could make was a line reasonably flat from 30 to 15,-

000 cycles at an initial cost, to be borne by the broadcaster, of more than \$75,000. The usual toll charges for use of the facility would follow. There could be no guarantee that the line would be noise-free. On that account, the radio program circuit was adopted as a major tenet of the plan, and Radio Engineering Laboratories furnished a unique 133-mc transmitter built to Major Armstrong's specifications at a fraction of the wire line cost.

Inaccessible Location

Mount Washington is remote from good wire lines. The broadcasting facilities designed to use to best advantage the summit of the peak were approachable, at best, through 7 miles of woods, to the foot of the mountain, and then three miles upward along a cog railroad. Although winter telephone communication has been maintained off and on since 1932 along this route, the cost of installing high-fidelity lines from the nearest suitable toll center and maintaining them in the high winds and other generally inclement weather would be extremely costly. Practically, the only way to program a Mount Washington transmitter is by radio link.

The techniques and equipment required for the relay system are simple, but the actual installations made were designed for less than optimum conditions. At the Boston studios (WEOD), a 3-element array of dipoles, reflectors and directors mounted one above the other on a steel mast on the roof of the building was used. At Paxton a pair of multiwave vee antennas, one above the other and each backed by a closely spaced parasitic reflector, furnished more than adequate gain for the program receiver used. In actual practice, the final amplifier in Boston was discarded at the time of a change in frequency assignment from 133 to 156 mc. Besides tolerating a power reduction at the relay transmitter, it was found that under conditions of abnormal icing at Paxton a simple dipole with reflector and director, mounted behind a glass-block wall near the 50-kw transmitter, furnished adequate signal for the program circuit.

On Mount Washington where small structures must be protected

from accumulations of ice or the force of superhurricane winds, a wooden tower was included in the special building design to house receiving or emergency transmitting antennas.

The receivers used in the relay technique were originally simply good f-m receivers built for Major Armstrong for general demonstration purposes. When Mount Washington went on the air, the General Electric type JFM-90 home receiver had become available and so this equipment was modified slightly for somewhat greater r-f gain and selectivity as well as for a more convenient output impedance. In general all these receivers were also provided with two audio outputs, one with a standard RMA restorer (de-emphasis circuit) for audio monitoring and the other maintaining the pre-emphasis introduced in the original transmitter. In this way, it is not necessary to restore and pre-emphasize the signal again at each succeeding station in the chain. At a later date, simple heterodyne converters were added to the JFM-90 receivers and they serve for reception on 156 megacycles as well.

Intercompany Relays

On Dec. 4, 1939, a program originating at W2XCR in Yonkers was picked up and relayed through W2XMN Alpine, then rebroadcast from W1XPW, operated by Franklin M. Doolittle at Meriden, Conn., since May 13, 1939. The success of this venture created considerable furore and K. B. Warner of the American Radio Relay League stated: "In 10 years there won't be any orthodox brand of broadcasting remaining except for the lowest grade of local service". Early in the morning of Dec. 29 a similar test program was tried again, this time including the Paxton transmitter. No difficulty was experienced when the Meriden program was picked up at a farmhouse somewhat lower in elevation than the station and sent through about a thousand yards of wire line to the transmitter modulator. The remote receiver and antenna were soon replaced by a local antenna and a receiver in the transmitter building. On Jan. 4 and again on Jan. 5, 1940, an hour's

program starting at 6 pm was originated in Yonkers and sent over the net for the benefit of regular listeners. Mount Washington received the program and relayed it by a-m to the communications center in Boston, where it was put on a telephone line and returned to Yonkers.

On Feb. 21, the Paxton program was successfully rebroadcast during a 15-minute test by the a-m stations WNAC Boston and WEAN Providence. With this success, a new chain was composed for a half-hour broadcast on the evening of Feb. 29, using W2XAG Yonkers (key station), W2XMN Alpine, W1XPW Meriden, W1XOJ Paxton and W1XER Mount Washington,—all f-m stations. In addition, the Alpine broadcast was picked up by a-m station WICC Bridgeport. Stations WEAN Providence, and WAAB Boston picked up the Paxton broadcast. Listeners in Boston to the Mount Washington f-m broadcast felt that it was fully as good as that from Paxton.

Further relay experiments conducted during 1940 were complicated by the continual violent evolution of the stations. At Paxton alone from May 1939 until May 1941 transmitter power was raised from 2 to 50 kilowatts and three different types of turnstile antennas were tried. One imposing 400-foot tower toppled over in an ice- and wind-storm early on the morning of Jan. 15, 1940. Every change in transmitting power or antenna required at least a slight change in the receiving setup.

Yet despite these difficulties it was possible to relay a live half-hour dinner music program from Meriden through the Yankee f-m network six days a week from January until December, 1941, as well as a number of other irregularly scheduled chain programs. On July 17, 1941, a special program was broadcast from Paxton for the dedication of W47A Albany, and thereafter for some time the bulk of the Albany station's program material consisted of rebroadcasts from the Yankee Network. On Nov. 30 the same year, the W71NY dedicatory program was heard over the network from New York after which live programs from Boston and

Hartford were relayed in the reverse direction through the Meriden station.

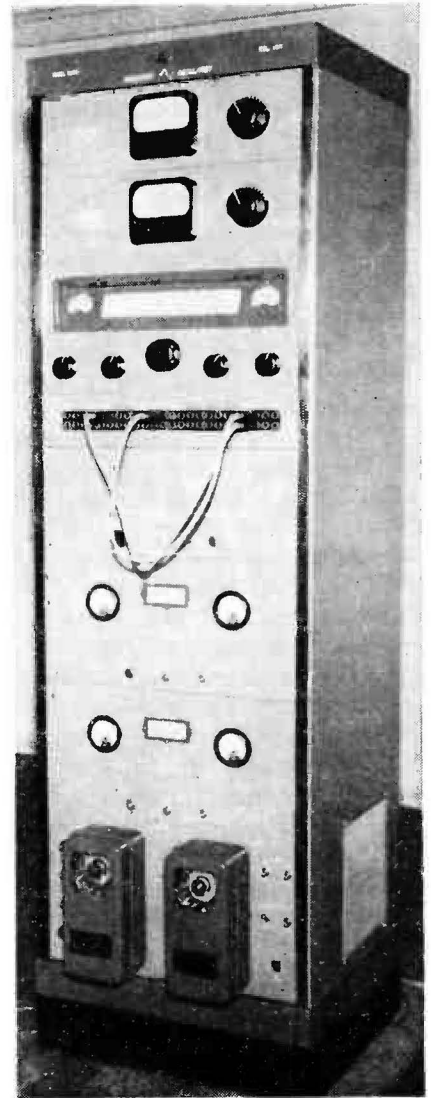
For three months, the Paxton programs were picked up at Trumbull, Conn., relayed on about 150 and later 200 megacycles, picked up at Alpine with a corner-reflector antenna on the middle arm of the famous tower, and fed via a coaxial line to the receiver that programmed the Alpine transmitter, providing a two-way circuit between Alpine and Paxton.

Some different relay techniques were also employed experimentally. Instead of receiving a signal, converting it to audio and using it to modulate another transmitter, the incoming carrier signal was caused to beat with a local oscillator so the difference frequency that was further amplified occurred at the assigned carrier frequency of the relay station. This system was used for some time with great success at Meriden in relaying to the north.

Beginning March 3, 1942, f-m chain broadcasting came of age when General Electric paid out cash money to sponsor the Frazier Hunt news program Tuesday, Thursday and Saturday evenings until May 29, 1943. The American Network chain included W53PH (now WFIL-FM) Philadelphia which picked up Alpine direct, W71NY (now WBAM) New York, W2XMN Alpine, W65H (now WDRC-FM) Meriden, W43B (Now WGTR) Paxton, W47A (now WBCA Schenectady) Albany and W39B (now WMNE) Mount Washington. The broadcasts went off with little technical difficulty, but unfortunately the program was transcribed—a fact only too apparent with the high-fidelity equipment used!

Postwar F-M

For a number of real and sufficient reasons, f-m broadcasting was unable to capitalize fully upon its rapid early gains and plateau of accomplishment after the cessation of hostilities in 1945. Because of the fear on the part of FCC that occasional long-range anomalous propagation would interfere with service areas far removed, new frequency assignments were made transferring the f-m broadcast band from 40–50 megacycles to 88–108 mega-



Radio-relay receiving panel used at FMA convention demonstration. Two vu meters for monitoring, high and low-band tunable receiver, jackfield, amplifier, and two fixed-tune receivers can be switched at will or automatically by time clocks below

cycles. Transmitters with any appreciable power were not immediately available for the new band.

With understandable if not commendable hesitancy, many manufacturers of receivers put off the evil day when a choice would have to be made whether to manufacture high-band or high-and-low-band f-m receivers, or no f-m receivers at all. F-m program material generally deteriorated or broadcasting time was cut because of an edict from the head of the American Federation of Musicians banning duplication of a-m programs on f-m stations unless suitable quid pro quo was forthcoming from the broadcasters.

Once again, under the aegis of the pioneers the Gordian knot has been

badly frayed. The Continental Network with WASH-FM Washington as key station, has been picking up since March 26, 1947 public-service concerts of Army and Army Air Force bands, relaying them by wire line and the rebroadcasting technique to an ever increasing network of f-m stations. Wire lines, necessary until the participating stations increase power or decrease distance between relays, constitute a bottleneck so far as fidelity is concerned. It has not yet been possible to obtain intercity telephone facilities that pass higher than 8,000 cycles a second so that with the exception of the key station, and despite the extensive radio links, (see map) the listeners lose a certain amount of the program's realism. The noise-free aspect is, however, a boon contributing a greater share to enjoyment than can be understood without listening.

It is probably not without significance that most of the relay circuits emanate from the older stations that are licensed to broadcast on both the low and the high bands. It is likely that consistent reception over distances possible with the low band may require greater power or more intermediates when the high-band frequencies are used.

At the moment of this writing Continental has grown to 28 stations, using 573 miles of wire line and over 1,400 miles of radio relays, and is still expanding rapidly. Starting Sept. 12, 1947, commercial operation of the network was begun with a half-hour program from WHFM Rochester sponsored by Stromberg-Carlson following a half-hour sustaining show. The schedule was varied on the first evening to include a pickup from the Frequency Modulation Association convention in New York where previously the delegates had heard Alpine broadcasts sent from Boston via three relays and one from Allentown, Pa. in two hops.

More than 90 applications have come in to Everett L. Dillard of WASH-FM, president of the Continental Network, requesting affiliation, one from the owner of a potential chain to cover California. There are inquiries from Florida and the Gulf states. The most immediate interest is in a plan that calls for a tel-

ephone line to Chicago with satellite relay stations branching from the wire line to the north and south.

Practical technical limitations to the length of a relay chain without wires is unknown, so that future plans for expansion will depend on further experience. The heterodyne frequency-changing method used successfully at the Meriden station is thought to be the most satisfactory solution, and the technique is being further developed experimentally.

The North Carolina State Hookup

The mountainous region in the Carolinas has proved, like New England, a fertile ground for f-m broadcasting. A-m signals are so rapidly attenuated that it is not economically feasible to give large segments of territory with small populations adequate or enjoyable service. F-m, on the other hand, is much less adversely affected by the terrain, particularly since high land is available for the siting of stations.

Plans are being formulated by the North Carolina FM Association for a statewide, one-time hookup of f-m stations that are on the air in time to participate in a broadcast to take place during National Radio Week, Oct. 26 through Nov. 2. A map included here shows the ten stations most likely to take part as heavy dots and the six remaining licensees as open circles. Relay paths expected to be used are indicated by solid lines. These circuits will probably be used in both directions as each station takes over as key station of the net, puts on its best program and then retires to a relay function as the next station originates rather than relays a program. The stations shown as squares are added to this map for convenience, but will not take part in the Radio Week hookup. The dotted lines show circuits that have been already tried experimentally or seem feasible for obvious reasons, indicating possible future potentialities for relaying.

Missouri-Kansas Net

Aside from the many inevitable studio-transmitter links connecting remote transmitters with their program source, there are other station

networks now in operation or in the formulative stage. Ambitious plans for a Missouri-Kansas network have been set into motion by the establishment of a receiving station atop the Kansan Hotel in Topeka, Kansas for reception of KOZY, Kansas City, Mo. One half-hour show each Sunday is by this means picked up and rebroadcast by WIBW-FM. As soon as station facilities at KOZY, now undergoing alteration, shall have reached a stable state more extensive hookups, possibly on a commercial basis, will be tried.

Owners of Radio Diablo, operating a 50-kw high-band transmitter, are considering establishment of a relay network that will tie together Los Angeles and Mt. Diablo, Calif. The latter station will then program transmitters in outlying communities roughly representing a hub to the spokes formed by the relay circuits.

Although f-m relays can do much to aid the growth of a new broadcasting service and the inexpensive dissemination of good programs, the time may eventually come when the f-m broadcaster will find it necessary to re-evaluate his position. A few moments, or even an hour of lost time from a sustaining program at this stage of the game can be tolerated, although it is undesirable. When more and more commercial programs are handled, the broadcaster may find that the additional expense of wire lines is still less than the maintenance of standby equipment at each station in a long chain. While it is still too early to predict the exact shape of the combined wire and relay facilities to be used by f-m broadcasters, it seems safe to assume that nearly as many miles of wire, coaxial, or microwave circuits will be used in the future as for the present major a-m networks.

Acknowledgments

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