Single Cable System Proposed fo

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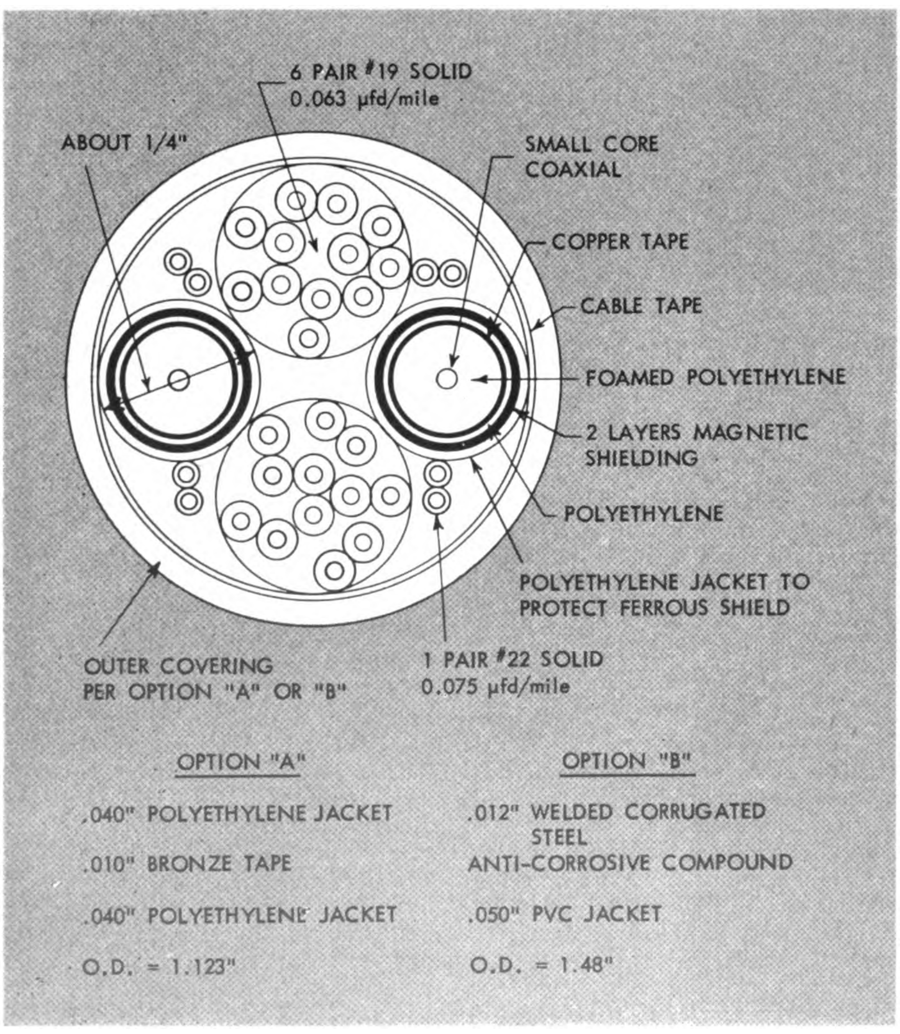
The signal and communications transmission services of the railroads are concerned with two basic services: long distance, and local or "dropping" circuits. Today, the accepted transmission method appears to embrace microwave radio for long distance circuits, leaving the local circuits on open wire.

For the future, the continued use of aerial installations for local circuits will not be economical except where the terrain is most difficult. The obsolescence of present pole lines and attendant high maintenance costs are receiving increased attention in railroad circles. Improved cable construction and installation methods point to the use of direct burial cables as a practical solution to the maintenance problems which accompany the use of open wire for local circuits.

When the burial, or even the aerial suspension, of some cabled circuits is considered, it makes economic sense to place all of the circuit requirements in a single cable in order to spread the cost of installation over a larger base. Broadband, or coaxial, wire circuits have received little consideration from the railroads for three reasons: (1) difficulty in obtaining suitable repeaters at reasonable cost; (2) comparatively high cost of suitable coaxial cables; and (3) comparatively high cost of installing coaxial cables.

When considering a wire transmission system from a cost viewpoint the objective is to minimize conductor sizes, insulation walls and protective coverings. When the same system is considered from the electrical viewpoint the objective is to maximize the transmission characteristics, a process which is generally contrary to the minimum cost philosophy. Total system design attempts to rationalize the cost and electrical considerations to provide a satisfactory operating system at the lowest possible cost.



The long distance, or broadband, circuits can be most economically handled on coaxial cables, while paired cables are the least expensive for handling local, or physical circuits, in the voice frequency range.

The broadband, or long distance, apparatus which meets the cost versus design criteria for most railroad applications involves the use of small-core coaxial lines and transistorized repeaters. For purposes of uniformity in transmission objectives and equipment standardization, the suggested system is very similar to one which is currently being added to the CCITT (International Telephone & Telegraph Consulting Committee) recommendations, and meets all of the existing CCITT transmission recommendations.

The least costly repeater arrangement, allowing for internationally recognized transmission objectives, spaces the repeaters at approximately three-mile intervals along two foam-insulated coaxial cables which are about ¼" in diameter. This configuration, using one cable east and one cable west, permits transmission of the band from 60 kc to 1,364 kc conforming to the first five 60-channel telephone supergroup allocations for both CCITT and Western Electric. Regulating pilots are provided at the limits of the band to operate level regulators at every fourth repeater in buried installations and at every repeater in aerial sections. The frequency spectrum below 60 kc is not used in this system due to the unjustifiable expense of providing heavy electromagnetic shielding on the cable. Power feed points for the repeaters can be spaced at approximately 75-mile intervals maximum, and entrance to the broadband circuits can be provided at all power feed points. Individual repeater alarms are led to the nearest power feed point.

The physical, or local, circuits along the railroad right-of-way have been fairly well standardized to No. 9 AWG copper or No. 6 AWG Copperweld for both audio and DC transmission. These wire sizes, in open wire configuration, are capable of transmitting signals over comparatively long distances. However, in the interest of keeping costs to a minimum, the amount of copper should

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also be kept at a minimum in a wire transmission system.

The advent of the all-tone CTC machine as well as tone signaling for dispatchers and message circuits appears to make the transmission of DC signals an unnecessary requirement in the future. For this reason, the eventual physical circuit should be regarded as an audio frequency circuit. The recent development of audio frequency repeaters as transistorized units now makes it possible to reduce the wire sizes required for local circuits and still retain the required transmission quality for both communications and signaling requirements.

With power feed points for the broadband circuits located at 75-mile intervals, permitting access to the broadband channels, the maximum circuit length can be held to about 37 miles. The 1,000 cps attenuation for 37 miles of No. 19 twisted pair toll cable is about 40 db. By locating a 20 db repeater near the circuit midpoint, all points along the line can be held to a minimum—20 dbm test tone reference level, which does not exceed the minimum level recommended by the railroads for dispatching and message circuits. Tone alarm and control circuits will function properly with this arrangement.

Maximum Circuit is 37 Miles

While some doubt has been inferred above about the suitability of the No. 19 AWG for transmission of DC signals, the 37 miles anticipated for maximum local circuit length will exhibit a loop resistance of about 3,200 ohms, and up to 30 type-60 selectors can be operated from a power supply of 250 volts or less. CTC line relays can also be operated along the 37-mile length of No. 19 conductors. The drawback to operating in this manner is that converters will be required at each broadband entrance point, while an all-tone system can be operated without converters.

The broadband repeaters, manufactured by Automatic Telephone & Electric Co., Ltd., are completely transistorized and deliver a gain performance of 33 db at the highest frequency of the transmission band. The repeaters are made in four configurations.

(1) A dependent, non-regulated repeater which is series powered through the coaxial center conductor. Equalizers, external test jacks and pilot output sensing alarms are provided. The repeater is housed in a moistureproof container (21″ × 21″ × 17″) and is installed in an underground concrete box.

(2) A dependent, regulated repeater which is identical to the one above, except that automatic gain-adjusting circuits are operated from a pilot level sensor.

(3) A terminal repeater containing the circuits of (1) and (2) above as required for matching multiplex equipment to the line. In addition, circuits are provided for the supply of constant current power to the dependent repeaters for alarm indicators and for order-wire amplifiers.

(4) A main repeater arranged as in (3) above, but equipped for operating as a repeater in both directions as well as matching terminating multiplex equipment.

This family of repeaters has been built in conjunction with requirements of the British Post Office (which operates the public telephone system). An experimental circuit of 15 repeaters was put into operation about three years ago. The first production circuits are now being installed in England.

The reliability of the repeater is largely dependent upon the reliability of its transistors. These are of one type, the OC170, a Philips development. The ATE laboratory has not, in nearly four years of work with the OC170, reported a single failure caused by events other than mishandling. No transistor failures were observed in the repeater trials. In fact, the circuit engineers concerned with the ATE repeater tend to regard the best capacitors as being no more reliable than these transistors.

The dependent, or unattended, repeaters are of plug-in construction. Circuit failures can be pinpointed through the alarm system. Exchange of repeater circuit modules can be accomplished by inexperienced personnel, and repair can be handled by most railroad radio shops.

The entire broadband system can be powered from regular commercial source, or from an office battery through solid-state converters. All dependent repeaters are placed in underground or thermally insulated locations in order to keep daily level variations caused by temperature variations at a minimum.

Audio frequency transistorized repeaters are being produced by Lynch Communications and by Stromberg-Carlson. Typical performance specifications show a gain of more than 30 db for a bandwidth of 300 cps to 9,000 cps. The repeaters may be operated in a two-wire configuration with suitable hybrids, or in a four-wire configuration with self-contained simplex taps for remote powering.

The broad frequency response of these repeaters will permit operation of several tone circuits, for teletype or telemeter information, above the normal voice band when the proper filters are provided. This fact, coupled with a trend towards reduction of way-station responsibilities may well limit the number of local service pairs required along most rights-of-way.

Composite Cables Have Been Used

Composite cables mixing voice pairs with coaxial lines have been used for a number of years by the telephone companies. Some of the drawbacks for application of these cable types to railroad communications services have been expensive jackets and, in most instances, the pressurization required for moisture elimination. New insulation materials and techniques have largely eliminated these objections.

The coaxial conductors are made up of a solid copper center with a foamed polyethylene insulation supporting the outer copper tape, which is held in place with another layer of polyethylene; this is followed with two layers of magnetic shielding and a final jacket of polyethylene to protect the ferrous shield. The resulting diameter is just over ¼″. The finished coaxial conductor has a characteristic impedance of about 75 ohms, matching the repeater, and an attenuation of about 11 db per mile at 1,300 kc.

The paired conductors for communication and signal service conform to No. 19 gauge toll requirements, being solid copper with a polyethylene wall sufficient to produce a mutual capacity of 0.065 mfd per mile. Other conductor sizes may be included in the cable for special services along particular sections of track.

A maximum of four No. 22 gauge pairs are provided for a four-wire order wire circuit which is completely independent of the broadband circuits, and for the repeater alarm circuits. In some cases it may be possible to reduce this arrangement to a minimum of two pairs if a two-wire order wire is accepted.

For direct burial service, the outer jacket consists of two high molecular weight polyethylene jackets separated by a bronze tape where required for rodent protection. For aerial service, and certain difficult installation points, such as trestles, a Simplex C-L-X impervious copper sheath is suggested as a rugged mechanical protection.

At all splice, way-station and repeater points an above-ground terminal box is planned. This will provide an easy access to test all lines at points probably not over two miles apart. A further important consideration for the above-ground terminal boxes is the ability to run patch circuits between the terminal boxes in the event of a disaster interrupting cable service along the right-of-way.

The expansion capability of the cable system takes into account expansion with available equipment for improved services, expansion with known techniques for further automation and centralized control, as well as expansion into areas which are still only theoretical.

CTC expansion is already available as an all-tone continuous-monitor system for long lengths of track. With the all-tone signaling, extended track control can be handled by channels in the carrier equipment, and alternate routing can be effected on leased telephone circuits during a disaster. A further expansion of this system, still within the capabilities of the cable system, will be computer control of trains in the entire railway system, with the dispatcher becoming a dispatch monitor for the railroad.

Dispatcher and message circuit expansion will initially call for improved service by substitution of tone signaling where the DC method is now employed. This will permit handling of the dispatcher line through voice-frequency repeaters which, in turn, will permit uniform transmission quality throughout the dispatcher's area. Addition of other areas or divisions to the central dispatching office will require addition of a voice carrier channel to each of the divisions concerned. Message circuit dialing, through all-tone signaling, is currently available. This type of circuit can be routed through one or more automatic exchanges to permit automatic way-station connection to all other telephones in the railroad system. Provision of this capability may require the addition of more message circuits for each division. Spare pairs can be made available in the cable for this service and the voice carrier equipment can be expanded to provide interdivisional trunks for message circuit dialing as required.

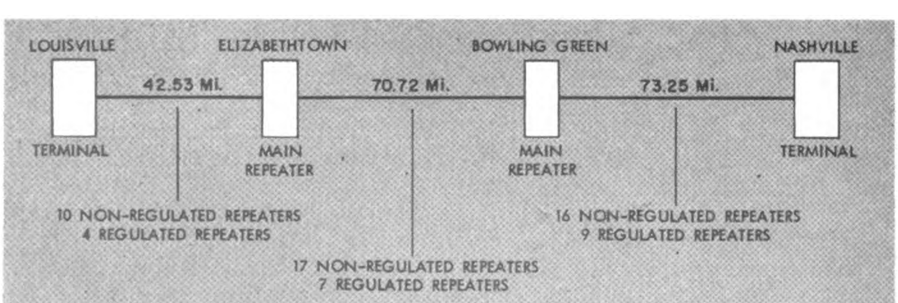
Voice carrier expansion can be provided up to a maximum of 300 channels. It is not anticipated that this number will be required along most rights-of-way. A realistic number would probably be 120 voice channels, leaving three supergroups of 240 kc each for future expansion in high-speed data or other wide channel requirements. Telegraph carrier circuits can be expanded to 16 two-way, 100 wpm teletype channels per voice channel.

Broadband channels of 240 kc each, up to a quantity of three, or a single channel of about 625 kc may be added when the telephone channels can be limited as noted above. A single 240 kc channel may be used to accommodate high-speed facsimile transmission for waybills. High-speed data may be added for linking two or more computers for decentralized control. The same high-speed data transmission capability may be used to more effectively process routing, train, or other operational information at a central location. It can also be used to process accounting and administrative information at a central computing facility. Another use for the broadband channels may exist in transmitting slowed-down video signals operating through scanning converters. Also the possibility exists for leasing some of the broadband services to other users, since one or more of these 240 kc channels may be dropped or inserted at any point along the right-of-way by adding a main repeater and appropriate filters. Additional broadband capacity can be provided when solid-state repeaters of greater gain characteristics become available.

In general, the proposed cable system, through its accessibility and versatility, can be expected to have more expansion possibilities than the present open wire systems which are supplemented with microwave routes. At any time, any location along the right-of-way can become a broadband entrance point by the addition of a main repeater. The transmission reliability of the cable system makes it directly adaptable to modern digital data handling devices without the addition of excessive error checking codes and the dependence upon empirically derived statistical distribution of transmission errors. Expansion of the system into these new data fields should be achieved in a shorter time and with greater economy than can be offered by any other type of transmission system.

In considering the economics of this

Item	Open Wire	Microwave	Cable
Initial equipment	In place	$1,400	$3,740
Installation	In place	100	990
Maintenance material	$ 625	75	75
Maintenance labor	4,000	2,000	2,000
Interest (5%)		975	3,074
Totals	$4,625	$4,550	$9,879
Full system total		$9,175	$9,879
Added cost			704
Tax on added cost (52%)			366
Net added cost to owners			$ 338
Annual net added cost per mile, first 25 years			$13.50
Annual savings per mile after 25 years			$185.00



Proposed cable system would be between Louisville and Nashville on the L&N.

proposed cable system, these points should be considered: (1) The cable system is always on the railroad right-of-way with continuous drop-out availability; (2) freedom from FCC regulations and changes; (3) freedom from the uncertainties of radio propagation constants and interference; (4) implementation in segments coinciding with certain outside plant retirement; (5) adaptability to future control and accounting schemes without relocation of routes; (6) lowered vulnerability due to malicious damage through concealment; (7) freedom from obsolescence by legal decree; and (8) utilization of present maintenance personnel without requiring significantly increased skills.

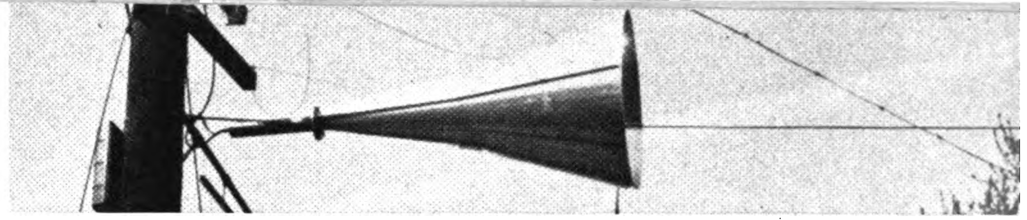
In a cost comparison between a coaxial cable system and a microwave system, the cable system would probably cost nearly three times as much as the microwave. However, when one considers that the railroad must continue to maintain an open-wire plant while using a microwave system, and can retire its open-wire plant in favor of a composite cable plant, more than simple acquisition costs must be weighed. Basing the life of any electronics or cable system on an estimated 25-year life span, the costs of the three types of transmission systems, exclusive of multiplexing and terminal apparatus which would be common to any broadband system, are shown in the chart. The estimate assumes that the open-wire plant is already fully depreciated and that rebuilding costs are not considered capital investment. Borrowed capital is repaid from the depreciation fund, as accumulated. While these figures show that the cable system costs more in actual dollars, it also shows that a wage increase of 10% would make the cable system less expensive.

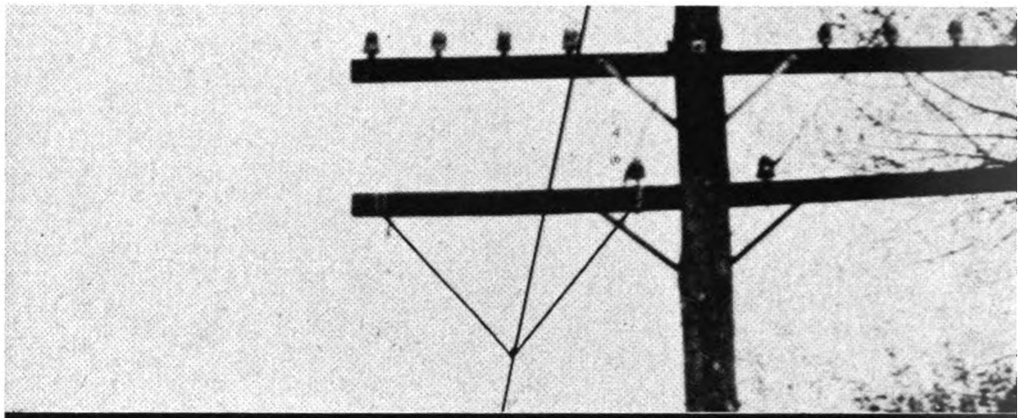
After the 25-year depreciation period, the savings with cable appear to be enormous. The maintenance difference, which becomes the only significant figure, amounts to a savings of $185 per mile per year for cable. Even if the cable maintenance cost should increase at the end of 25 years to equal the present open-wire maintenance cost, which is unlikely, there would still be an apparent savings of more than $80 per mile per year by using the cable system.

The study made for the L&N involved the interconnection between Louisville and Nashville, 186.5 miles, of which 18.65 miles is considered to be installed on poles and 1.86 miles on trestles; the balance is considered to be buried cable. The broadband frequency allocations were devised so that channels on supergroup I could be dropped and inserted at the main repeater points. Supergroups II through V were arranged as through circuits, with only supergroup II handling telephone and telegraph traffic. Supergroups III through V were reserved for future data services.

It appears that the single cable system for the transmission of communications and signals along the railroad right-of-way is now technically feasible. All of the materials are available to perform the services required today and in the predictable future. High speed data capability at any point along the right-of-way is a technical advantage which may make an entirely automated railway system possible.

The economic feasibility of the single cable system depends largely on the operating environment today. Within five years, however, it is expected that cable and apparatus developments will have progressed to the point where the single cable system will cost less than present techniques under any conditions. **RSC**





One Wire Can Handle Broadband Transmission

Broadband transmission can also be accomplished via a single-conductor insulated wire, known as the G-Line. It has been used in community television antenna systems, and a test installation on the New York Central showed its capabilities for possible railroad usage. In the NYC test, the G-line was a No. 6 Copperweld (40% conductivity) wire with a polyethylene coating. It extended from Nepperhan to Ardsley, N. Y., 4.5 miles. At each end, the G-line terminated in a horn which was connected to the station by 100 ft of RG-11/U coaxial cable. The G-line was mounted on the lowest cross-arms by nylon loops. The line was between 5 and 20 ft above the ground and at least 2 ft from other objects. Total loss of the line in the test was about 45 db or 10 db per mile. Without intermediate amplification, four television channels were transmitted simultaneously, two channels in each direction, on frequencies corresponding to TV channels 6 (82–88 mc), 8 (180–186 mc), 10 (192–198 mc) and 12 (204–210 mc). Tests were conducted by Surface Conduction Inc., in cooperation with the railroad.

This paper was presented at the 1961 AAR Communication and Signal Section convention in Toronto.