Program Transmission Over Type-*N* Carrier Telephone

R. L. CASE
MEMBER AIEE

IDEN KERNEY
NONMEMBER AIEE

THE transmission of program material over a nation-wide system of wire-line networks interconnecting most of the country's broadcast and television stations has grown apace with the development of the radio and television arts. Today, program networks aggregating as much as 156,000 miles in length, including both radio broadcast circuits and television sound channels, may be employed during a single evening.

Initially, all program networks operated over voice frequency facilities, either open-wire or cable. The open-wire circuits were nonloaded, but the cable circuits, other than short runs in metropolitan areas used to connect studios and transmitters, were, in general, equipped with special loading, and the transmission variations with temperature were controlled by pilot-wire regulators. The voice frequency cable pairs assigned to program transmission were usually 16-gauge, so that the program levels in each repeater section might be maintained at adequate values, and the repeaters still spaced far enough apart to permit their being placed at the same locations as the message repeaters.

In 1945, program transmission on a commercial basis was first provided for each of the major networks over *K* carrier facilities between Los Angeles and Omaha, utilizing three message channels to provide a single program channel in each *K* system.[1] However, as only a few of the broadcasters requested facilities with a wider band than that provided by schedule *A* program (approximately 100–5,000 cycles) the program terminal was modified to permit one of the three channels to be returned to message service.

With the advent of the less expensive type-*N* carrier system[2] about 3 years ago, the possibility of both schedule *A* and schedule *C* (approximately 200–3,500 cycles) program transmission over one or two links of this facility became of great interest. This was partly because of the flexibility of the proposed arrangements and partly because of the economies envisioned. With the increased use of television facilities a high speed of propagation for the sound channel was required so as to synchronize properly with the video channel, a speed not possible with long voice frequency loaded pairs. In addition, in anticipation of the use of program over carrier, new cables, both quadded and nonquadded, were being fabricated without any 16-gauge pairs.

Schedule *A* and *B* (part time schedule *A*) program requires a band which is wider than the total frequency space allotted to a type-*N* channel. To obtain this band with existing type-*N* arrangements, it is necessary to give up three message channels. While schedule *C* and *D* (part-time schedule *C*) program requires the band space of only a single-message channel, it is necessary to widen the message band and to eliminate the 3,700-cycle built-in signaling system.

Engineering Considerations

Prototype program channel units providing schedules *A* and *C* transmissions were tried out on two Milwaukee-Madison experimental *N* systems in 1950. Exploratory work was also carried out to determine the feasibility of providing 8- and 15-kc facilities over these systems. As there were few commercial requirements at that time for program service with a band wider than that provided by schedule *A* facilities, it was decided to concentrate on the development of channel units for schedules *A* and *C* program transmission.

The Milwaukee field investigation indicated that while satisfactory program transmission was readily realized over type-*N* carrier systems in fair weather, excessive static interference resulted during severe electrical storms in the vicinity of the Milwaukee-Madison cable. Various remedial measures were tried on the *N* systems themselves, such as application of direct drainage on the *N* pairs; application of roof (low-pass) filters at the inputs of high-low repeaters and of cellar (high-pass) filters at the inputs of low-high repeaters, and substitution of a local battery supply for the individual repeaters in place of the power supply usually fed over the *N* pairs. These measures offered only minor reductions in the static disturbance, so it was concluded that most of the noise was introduced through the open-wire taps along the cable. However, because of the large number of taps involved it was not found practicable to apply suppression measures to them during the 1950 static season.

The following year, another series of tests was conducted, this time on an *N* system operating over the Harrisburg-Sunbury, Pa., toll cable, which, when the field study began, had only a single open-

Paper 53-335, recommended by the AIEE Wire Communications Systems Committee and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Pacific General Meeting, Vancouver, B. C., Canada, September 1–4, 1953. Manuscript submitted May 25, 1953; made available for printing July 13, 1953.

R. L. CASE and IDEN KERNEY are with the Bell Telephone Laboratories, Inc., New York, N. Y.

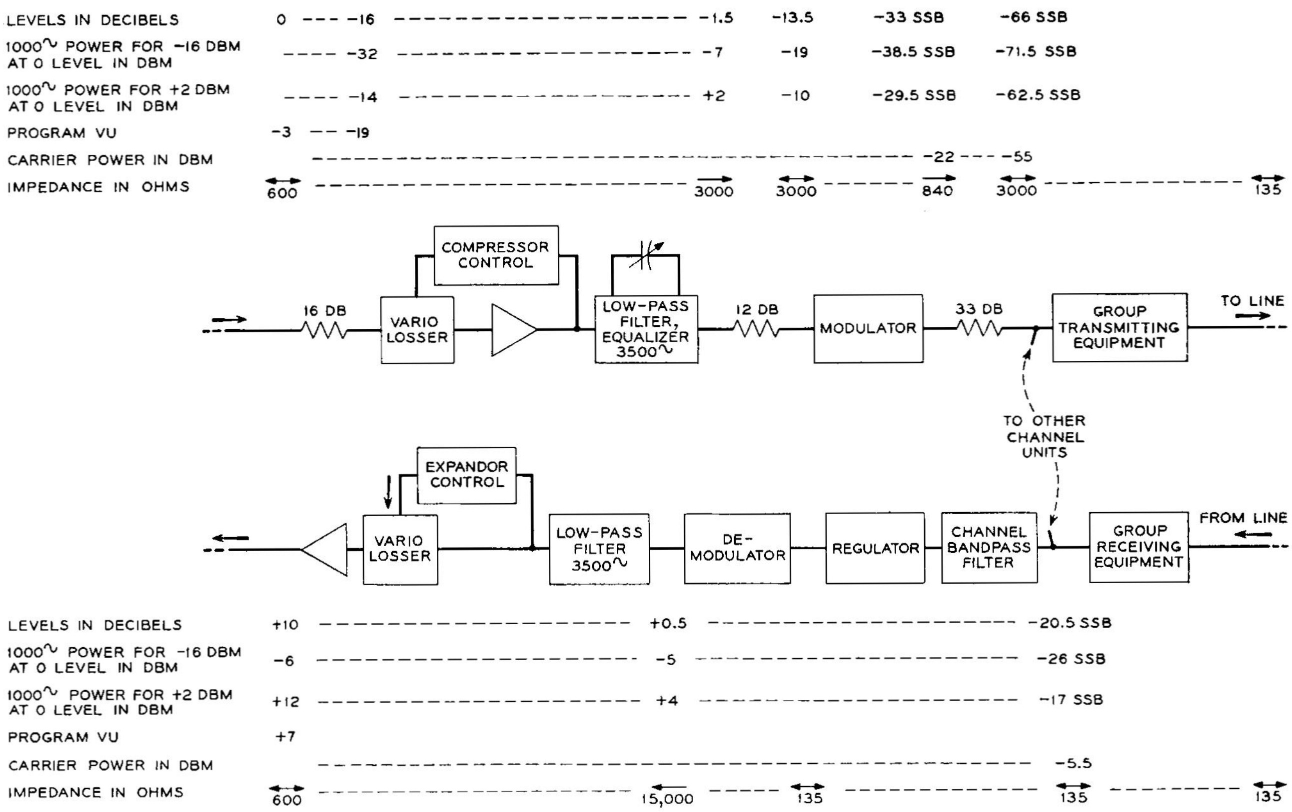


Fig. 1. Block schematic of schedule C compressor and expandor, level diagrams included

wire tap location with two open-wire pairs entering the cable at that location. Means were provided at this junction for switching suppression filters in or out of the circuit as desired, one filter being supplied for each of the two open-wire pairs.

The observed effectiveness of the suppression filters located at this tap was found to be about 20 decibels (db), a value great enough to permit satisfactory schedule *C* program transmission even under storm conditions. While no tests have been made on schedule *A* performance when a severe electrical storm was centered over one or more of the open-wire taps, it is expected that such suppression will also permit the use of these wider band program facilities during periods of high static noise. To obtain satisfactory year-round program service over *N* systems, it may be necessary to treat each and every open-wire pair at its junction with the cable carrying the *N* pairs.

Type-*N* carrier will provide more economical program circuits than can be obtained with voice frequency facilities, which, though meeting the technical requirements, are inflexible. For example, in planning for schedule *A* program service over such voice facilities, a sufficient number of program pairs must initially be fabricated in the cable, not only to take care of immediate requirements but also to provide for future growth during the life of the cable. In addition, the program pairs must be specially loaded (*B-22* or *B-44*), and, if the toll cable in which these pairs are located is aerial, pilot-wire regulation must be furnished for the associated program amplifiers along the circuit, as well as for the 2-wire and 4-wire message repeaters. This can be an expensive addition when only a small number of voice circuits is involved.

The design of the *N*-carrier-derived schedule *A* program system makes use of all of channel 6 and of a 1-kc band in channel 5 and in channel 7. If there is a paralleling *N* system operating in the same cable, crosstalk which might result from the 3,700-cycle signaling tones of that system, could show up at the receiving schedule *A* terminal as a 3,700-cycle tone effected by the channel 6 upper and lower side bands of 3,700 cycles; a 4,300-cycle tone effected by the channel 5 upper side band, and a 4,300-cycle tone effected by the channel 7 lower side band. The disturbing effect of these tones is of a different nature when several *N* systems are operating in the same cable, in that the 3,700-cycle signaling oscillators of the various *N* systems are not in synchronism and are random in frequency at about the 3,700-cycle point. To add to this randomness, the channel carrier frequencies and the repeater carrier frequencies in the various systems in the cable also differ from each other. If there is also an *ON* system[3] operating in the same cable, crosstalk from one of its carriers could be transmitted through the program terminal and could show up as a 4-kc tone. When more than one *ON* system is operating in the cable, the effect of the 4-kc tones may be somewhat like that of the interference from multiple *N* systems just described. The results of a recent field study of schedule *A* program transmission operating over *N* carrier in a nonquadded cable between Bangor and Presque Isle, Me., showed that there was a tendency for the disturbance from the 3,700-cycle signaling tones of other *N* systems in the same cable to approach resistance noise in character. The values of the total interference from these random tones were found to be acceptable even over such a long nonquadded cable. While there may be marginal cases of *ON* interference,

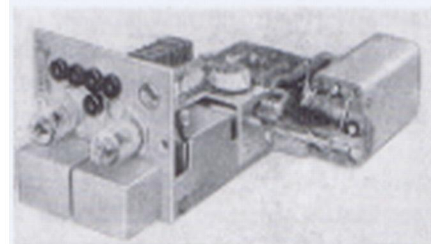


Fig. 2. Schedule C compressor subassembly

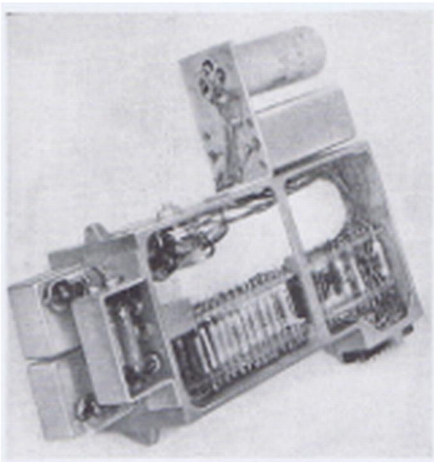


Fig. 3 (left). Schedule C expandor subassembly

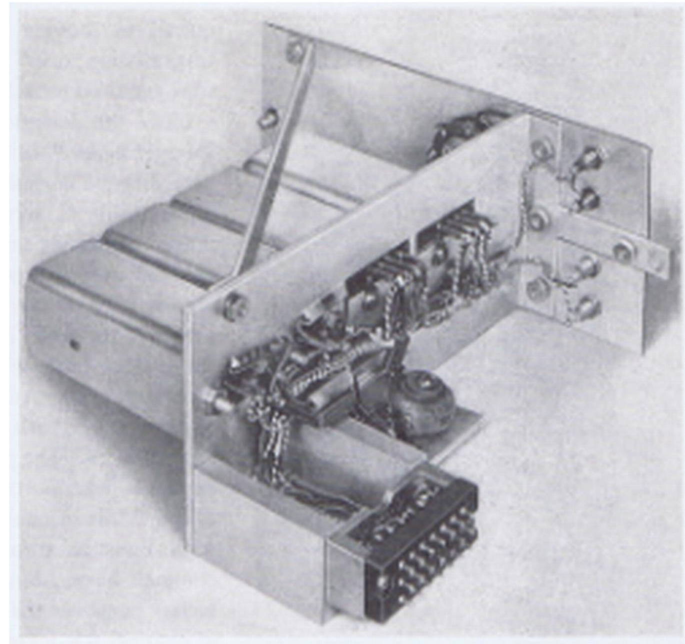


Fig. 5 (right). Schedule A low-frequency subassembly

it is believed that, in general, satisfactory crosstalk values may be realized by the selection of pairs or by a reduction in *ON* carrier level, or both, when a nonquadded cable is employed. The use of quadded toll grade cable should permit the operation of other *ON* or *N* systems in the same cable as schedule *A* program, without any special precautions, and with a reasonable assurance of low levels of disturbance present in the program channels.

Design of Program Channel Units—General

By making certain modifications in the type-*N* terminal channel unit, it is possible to replace any type-*N* message channel unit by a modified unit, and provide schedule *C* program service over that particular channel. One or more schedule *C* program channels may be used on a type *N* system.

To transmit the higher grade schedule *A* program over an *N* system, however, requires more elaborate changes. In the present design three specific message channels of the *N* system are relinquished and are replaced by one schedule *A* program channel. However, one message channel may be recovered by using the space of one of the channel units for the addition of a higher frequency channel unit now under development. Provision is made for the application of only one schedule *A* program circuit to an *N* system. External equalizers, predistorting and restoring networks, and compandor with a wider frequency band are required. All these items are presently available. No modifications of any kind are necessary in the type *N* group units or repeaters for either schedule *C* or *A* program.

Schedule *C* or *D* Program Channel Unit

Like the type-*N* message channel units, the schedule *C* program channel unit consists of a compressor subassembly, an expandor subassembly, and carrier subassemblies. The program compressor and expandor subassemblies are the same for any one of the 12-channel units. The carrier subassembly with its carrier frequency modulating oscillator and band filter is different for each channel unit but is the same for message and program units.

The compressor and expandor subassemblies, however, were considerably modified for program use. Since the program circuits are always operated on a 1-way basis, the 2- or 4-wire terminating equipment was removed and the transmitting low-pass filter and equalizer on the compressor subassembly were modified to extend the band down to 200 cycles and up to 3,500 cycles. An adjustable feature is provided in the high-frequency part of the equalizer to take care of variations that may be present in the over-all circuit. All signaling equipment was removed from the expandor subassembly and the receiving low-pass filter was modified to extend its band to 3,500 cycles.

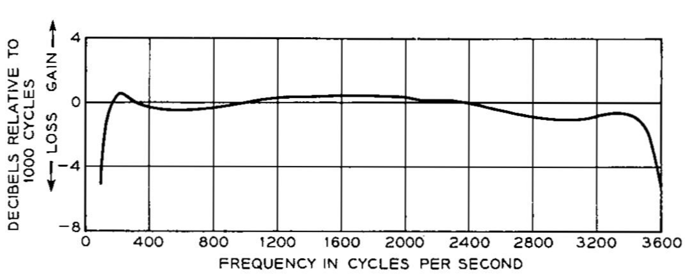


Fig. 4. Typical transmission frequency characteristic of schedule C type-N single link with ten intermediate repeaters

Additional filtering was provided in the plate circuit of the compressor and expandor so that different programs could be transmitted in both directions simultaneously over the same channel unit with negligible crosstalk between them.

A block schematic of the compressor and expandor subassemblies is shown in Fig. 1, and views of the equipment in Figs. 2 and 3. Minor alterations were made in the message unit die castings, and simple brackets were added to accommodate the additional circuit elements.

A typical over-all transmission frequency characteristic for a schedule *C* type-*N* link is shown in Fig. 4. It will be noted that the characteristic is flat within ±1.5 db over the 200- to 3,500-cycle band.

When the internal noise generator provided in the *N* system to mask crosstalk is adjusted to give +33 decibels adjusted of noise on message circuits at the +10 level point, the noise on the schedule *C* program channel at the +8 volume-unit point is well under a reasonable objective for this class of service. The crosstalk between message and program channels or from program-to-program channels is negligible.

The program unit mounts interchangeably with any message unit. To provide program service over a particular channel, it is only necessary to remove the message channel unit from its plug-in

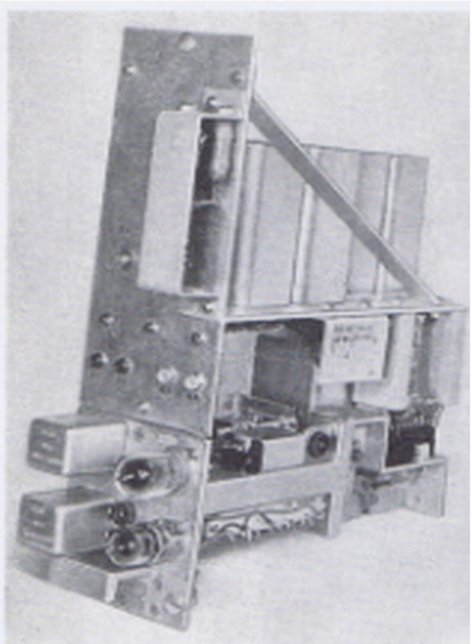


Fig. 6. Schedule A channel unit consisting of low-frequency and carrier subassemblies

socket and replace it by the program unit having the same channel number. If desired, the carrier subassembly may be removed from the message unit and reassembled with the program compressor and expandor subassemblies to form the new program channel unit.

The heater power required for the program channel unit is less than for the message unit but the program unit has a resistance load added so that the total heater battery drain for the program unit is the same as for the message unit. Thus no readjustment of the resistances in the heater battery supply circuit is necessary when changing from message to program units or vice versa.

Schedule *A* or *B* Program Unit

The transmission characteristics of the compressor and expandor of the type-*N* channel unit make them unsuitable for the wider band of the schedule *A* program. Likewise, the 4-kc wide-channel band-pass receiving filter is unsatisfactory for 5-kc transmission. Consequently, more elaborate changes are required to provide schedule *A* program transmission over type-*N* carrier than were required for schedule *C*.

Since the demand for schedule *A* service over type-*N*, initially at least, is expected to be considerably less than that for schedule *C*, arrangements have been made to provide only one 5-kc program channel over a type *N* system. This is obtained by removing message channel units 5, 6, and 7, and by replacing these three units with one program unit having a carrier subassembly similar to channel 6 but with a 5-kc wide-band receiving filter. The program band now occupies a 1-kc portion of both channels 5 and 7 but of course does not interfere with message transmission since those channels have been removed. For regulating purposes the transmitted carrier of channel 6 is increased 5 db in order to maintain the same total transmitted carrier power of the 12 channels as existed when channels 5, 6, and 7 were used for message service. With the channel 6 carrier increased 5 db, the program input to the modulator is increased a corresponding 5 db in order to gain signal-to-noise improvement.

The message compressor and expandor subassemblies are replaced by a single unit consisting of an equalizer and transformers so that the 600-ohm sending and receiving voice frequency program circuits may be properly coupled to the modulator and demodulator circuits on the carrier subassembly. These units are shown in Figs. 5 and 6.

The channel 6 unit is built out to take the same heater load as the corresponding message unit. To avoid the necessity for any readjustment of heater voltage, plates are provided, each of which is equipped with a resistance to take the same heater load as would be taken by a message channel unit 5 or 7. These plates may be plugged into the blank spaces caused by removing channel units 5 and 7. Fig. 7 shows a plate with heater load resistance.

The schedule *A* program unit can of course be readily plugged into the place of the channel 6 message unit. A view of a type-*N* terminal equipped with a schedule

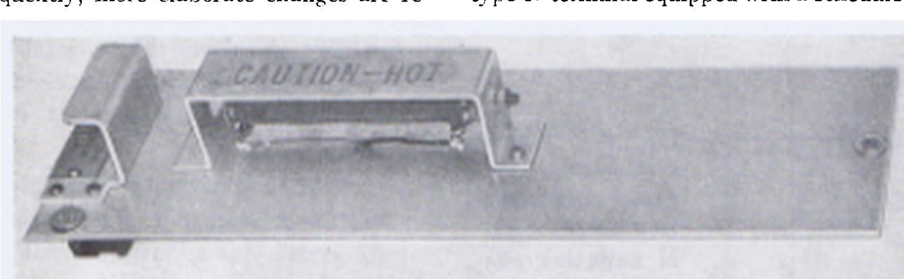


Fig. 7. Plate with heater load resistance

Fig. 8. Type-N terminal equipped with schedule A channel unit and plates. Engineer inspecting schedule C unit

A channel unit is shown in Fig. 8. The engineer in the photograph is inspecting a schedule *C* channel unit.

The 1*A* compandor is used external to the *N* system to provide part of the improvement in noise and crosstalk performance desired for schedule *A* program. The 1*A* compandor has a range of compression and expansion similar to the type *N* compandor but has a bandwidth suitable for the schedule *A* program.

Further improvement in noise and crosstalk is obtained by the use of the 200-type predistorter and restorer, devices to partially equalize the power of the low and high frequencies at the sending end, and restore them to their normal relationship at the receiving end. A 5-kc low-pass filter is placed at the transmitting end to prevent extraneous frequencies above the program band from causing interference into the adjacent type *N* channels. Equalizers are furnished at the receiving end as required to meet the over-all transmission objective.

A block schematic of the over-all schedule *A* program system, together with a level diagram, is shown in Fig. 9. The circuit is arranged so that different programs can be transmitted simultaneously in the two directions. With the arrangement shown in Fig. 9 it is expected that the transmission will be flat within ± 1 db over the band from 100 to 5,000 cycles, as shown in Fig. 10.

It will be noted that by using the channel 6 carrier frequency for the program-modulating frequency, any crosstalk from carriers of other *N* systems in the same cable either falls on the program carrier or

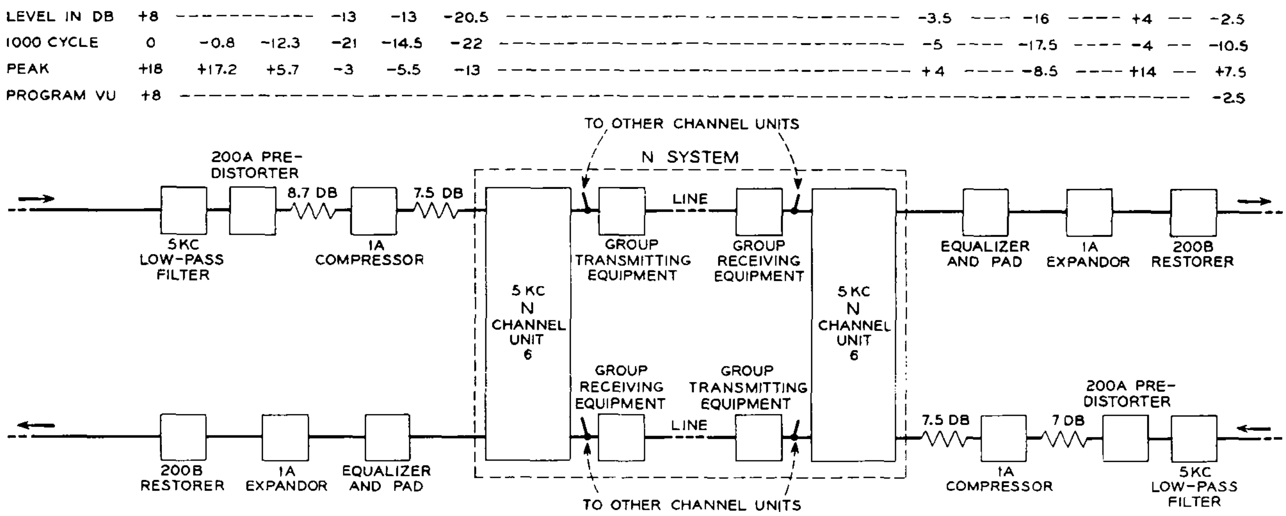
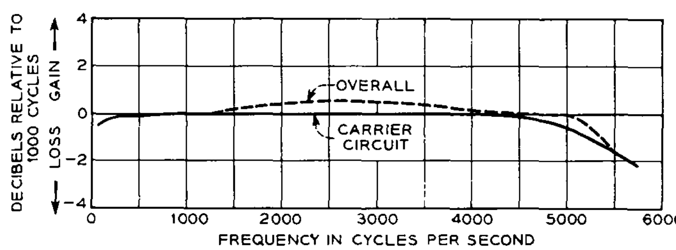


Fig. 9 (above). Block schematic of schedule A program system

Fig. 10 (right). Typical transmission frequency characteristic of schedule A type-N single link. Over-all characteristic includes external equalizers, predistorting and restoring networks, compandor, and 5-kc low-pass filter



falls outside the program band. A rearrangement of the carrier modulator of the schedule *A* program system, so as to employ only two channels of band space instead of three in the *N* system, would have introduced more co-ordination problems with the carriers of the other *N* systems.

Reversal Arrangements for Schedule *A* Program

Although program over *N* carrier is usually limited to the last one or two links of a program network, provision for reversing must be considered, since all or part of the particular program may originate at the end of the network, for example, when the President of the United States on tour broadcasts from his train while it is held on a siding at some small locality. Circuit arrangements to provide for this reversing are now under development. With these arrangements, only one direction of transmission of the program at a time is used, the direction at any time being controlled by the customer or telephone company as required.

The relay-reversing arrangements for the voice frequency part of the circuit are similar to those used for other standard program circuits. To reverse the carrier part of the program circuit, a new unit is being designed to be used in place of channel 5. This unit will have a channel 5 carrier oscillator of somewhat lower amplitude than the normal message carrier so that the transmitted tone will not appreciably affect circuit regulation. This new channel 5 carrier oscillator will provide the transmitted reversal tone under control of the transmitting directional setup. Transmission of the channel 5 carrier oscillator tone over the circuit conditions the circuit for transmission in that direction. A crystal pick-off filter and receiving circuit are used to identify the tone sent by the distant end. The receiving channel regulator is eliminated to avoid large increases in receiving again with possible false indications when the reversing tone is removed at the sending end. The channel 5 reversing unit is built out to take the same heater load as the corresponding message unit and can readily be plugged into the channel 5 space.

Typical Bell System Application

A number of schedule *C* and *D* program systems are already in operation. It is expected that by the end of 1953 schedule *A* and *B* program transmission will be operating over *N* carrier systems between Joplin and Springfield, Mo.; Santa Ana and Los Angeles, Calif.; and Duluth and Minneapolis, Minn.

References

1. A SYSTEM FOR 8,000-CYCLE PROGRAM TRANSMISSION. *Electrical Engineering*, vol. 68, May 1949, pp. 395–400.

2. A NEW TELEPHONE CARRIER SYSTEM FOR MEDIUM-HAUL CIRCUITS, R. S. Caruthers, H. R. Huntley, W. E. Kahl, Ludwig Pedersen. *Electrical Engineering*, vol. 70, Aug. 1951, pp. 692–97.

3. TYPE-*ON* CARRIER TELEPHONE, R. D. Fracassi, H. Kahl. *AIEE Transactions*, vol. 72, pt. I, 1953 (Jan. 1954 section), pp .713-21.

No Discussion