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Next 1 Page(s) In Document Denied

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EQUIPMENT OF THE K-12 12-CHANNEL SYSTEM (CONCLUSION)

(Conclusion; for first part see No 6, 1952)

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Line Amplifiers

The principal units of the K-12 apparatus, constituting a part of all terminal and intermediate stations, are the line amplifiers. In accordance with the 3 types of intermediate stations, 3 types of line amplifiers are used in the apparatus: without ALC, with flat ALC, and with flat and sloping ALC. The latter amplifiers represent the most complicated type and are employed not only in the intermediate but also in the terminal stations where they are called the line reception amplifiers.

All line amplifiers contain the same principal portion -- the amplifier proper; they differ from each other only in the external (interstage) negative feedback chain and by virtue of the fact that they have a set of correcting networks connected at the input of the amplifier. The same principal portion of the amplifier, with slight variations and with a very simple external feedback chain, is used as a transmission amplifier at the terminal station; this amplifier has an amplification characteristic that is independent of the frequency.

The simplified principal diagram of the line amplifier with flat and sloping ALC is shown in Figure 6. The doted lines divide the circuit into portions whose elements are placed in individual blocks.

The amplifier-proper block, which is identical in the line amplifiers of all types, is shown in the right upper part of the diagram. It contains 3 stages of amplification employing 10Zh1L tubes if local electric supply is used or 12Zh1L tubes if remote supply is used.

The first 2 stages with tubes V_1 and V_2 are voltage amplifiers, and the last (output) stage with 2 tubes V_3 and V_4 in parallel is the power amplifier. The stages of the amplifier are resistance coupled. The fixed bias is produced on the control grids of the tubes by a voltage drop due to the d-c components of the plate currents and screen-grid currents across the corresponding resistors connected in the cathode circuits of the tubes.

Heavy negative feedback is employed in the amplifier, insuring stability of the amplifier with fluctuations in the source of supply and the required nonlinearity attenuation in the amplifier. Three negative feedback chains are used: one outside interstage chain and internal chains in the first and third amplification stages. The external chain and the internal chain in the third stage produce a combined current and voltage feedback. The internal feedback in the first stage is current feedback.

A potentiometer connected at the input of the amplifier permits frequency-independent variation of the gain in steps of 0.3 nepers each to compensate for the attenuation of line sections of different lengths. With the aid of this potentiometer it is possible to adjust the gain within a range of 3.9 nepers.

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A so-called constant slope network CSN is connected in the external feedback chain to compensate for the slope of the frequency attenuation characteristic of a cable-line section 30 km long. Connected at the input of the amplifier are 4 equalizing networks EN having characteristics that slope in a direction opposite to the frequency characteristic of the cable-line attenuation of different length, and an actual-slope network with a characteristic corresponding to the actual attenuation characteristic of the cable line. By using these networks in varying combinations and by reconnecting the input potentiometer and the lengtheners -- which have a total attenuation of 1.35 nepers (in steps of 0.15 nepers each) -- in the amplifier feedback chain, the resultant frequency characteristic of the amplifier gain is made to compensate for the attenuation of amplifier sections ranging from 20 to 54 km in length, with an accuracy to within one km. All these reconnections are effected by means of soldered joints.

It is possible to change the frequency characteristics of the amplification of the amplifier without resoldering the connections (by changing the settings of contact jumpers) with the aid of variable resistors A and B which are connected in the external negative feedback chain. The former of these resistors is connected directly into the circuit, and the second is a load resistance for network C. The main purpose of resistors A and B and of network C is to adjust the gain of the amplifier so as to compensate for variation in attenuation of the cable line produced by temperature fluctuations. Resistor A makes it possible to change the gain by an equal amount at all working frequencies within a range up to ±0.35 nepers. Resistor B together with network C permit changing the slope of the frequency characteristic of the gain in such a way that the value of gain at 12 kc changes within a range of up to ±0.55 nepers, while the attenuation remains almost constant at 56 kc.

The frequency characteristics of the gain of a line amplifier with flat and sloping ALC at different lengths of line section compensated by this amplifier and at an average temperature of ±5° are shown in Figure 7. The same figure shows dotted the amplification characteristics, which are obtained at the extreme values of resistors A and B for the limiting values of section length, namely 20 and 54 km.

Amplifiers with flat ALC contain only one EN network at the input; in all other respects this amplifier is a complete duplicate of the amplifier with flat and sloping ALC.

The amplifier without ALC differs from the amplifiers considered above in that it has no EN network but has a principal-slope network in the feedback chain to insure equalization of the characteristics of a 44 km cable line, and also has not one but 3 actual-slope networks at the input. The feedback chain of the amplifier without ALC is provided with a set of lengtheners adding up to 2.05 rather than 1.35 nepers. This amplifier is designed to compensate the attenuation of amplifier sections ranging from 20 to 57 km with an accuracy to within one km.

In addition, line amplifiers with flat ALC and without ALC contain a low pass filter, which protects the input of the amplifier against the entrance of noise in the frequency range below 12 kc, produced principally by crosstalk from low-frequency pairs in nonloaded cable pairs.

The use of gain adjustment and constant-slope networks in the negative feedback chain of the line amplifiers reduces considerably the effect of thermal noise produced in the resistances connected at the amplifier input. Were all the gain and frequency-characteristic slope adjustments

STAT

to be effected with the aid of equalizing networks and lengtheners connected at the amplifier input, the thermal noise would in all cases be at a level corresponding to the maximum gain used for the compensation of a maximum-length section.

The heavy negative feedback in the amplifier, amounting to approximately 5 nepers at 60 kc for an average length of section (external feedback plus feedback in the output stage) also reduces considerably the nonlinear distortion introduced by the amplifier. The characteristics of the dependence of the nonlinearity attenuation in the second and third harmonics on the output level of the amplifier (power) are represented in Figure 8. The measurements were made at the indicated 60-kc harmonic with an amplifier gain equal to 6.8 nepers.

The accuracy with which the frequency characteristics of the line attenuation are corrected with the aid of networks in the line amplifiers is sufficiently accurate. However, if there are many amplifier sections, the correction errors accumulate and their sum may become excessive. To eliminate these errors the K-12 system employs supplementary correcting networks (equalizing systems) installed in the intermediate and terminal points of every fifth or sixth amplifier section.

Installations for Automatic Control of the Transmission Level

The K-12 apparatus employs purely electrical automatic level control, effected with the aid of thermistors. With this, 2 separately acting automatic level controls are employed, each regulated by an independent control-frequency current: "flat," using a 56-kc control frequency, and "sloping," using a 16-kc control frequency. The above currents are transmitted over the line in both directions.

It was indicated in the description of the line amplifier circuit (Figure 6) that by varying resistances AB, connected in the external feedback chain of the amplifier, it is possible to change the gain of the amplifier independently of the frequency ("flat" control) and to change the slope of the frequency characteristic of the amplifier ("sloping" control). It is possible to replace resistors AB in the negative feedback chain of the amplifier by indirectly-heated thermistors Tr-1 and Tr-2 of the TKP-300 type. The resistance of the thermistor is regulated with the aid of its heater circuit using the corresponding control-frequency current. The working body of the thermistor, made of a semiconductor and having quite small dimensions (fractions of a mm) is surrounded by the heater winding and is placed in an evacuated glass bulb. A typical characteristic of the dependence of the working-body resistance on the heater current for the type PKP-300 thermistor is shown in Figure 9. The maximum power dissipated by the heater winding is 20 mw.

Automatic control insures the constancy of the level of control-frequency current at the output of the line amplifier with an accuracy of ±0.07 nepers at a change of level at the input of amplifier by ±0.35 nepers in the case of flat regulation and ±0.5 nepers in the case of sloping regulation (at the 16 kc frequency). For the 12 kc boundary frequency of the line spectrum the limits of the sloping regulation are ±0.55 nepers. Such limits result in enough compensation for variations in cable attenuation resulting from fluctuations in soil temperature to cover 3 amplifier sections employing flat regulation and 9 amplifier sections employing sloping regulation.

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In the receiver channel of the terminal stations the control frequency currents are separated from the total transmitted spectrum by narrow-band quartz filters connected in parallel with the output of line amplifier A (Figure 3); from there the currents flows into the input of the control-channel receiver (CC rec). In the latter they are amplified, converted into 3 kc auxiliary-frequency currents and applied to the heater winding of the thermistor.

The control channel receiver circuit is so designed that insignificant fluctuations in the control frequency current at the output of the line amplifier cause very large changes in the auxiliary frequency current applied to the heater winding of the thermistor. This results in the required limits and accuracy of the control. The receiver contains 2 type 10Zh1L tubes and an auxiliary indirectly-heated thermistor. The first tube is used to amplify the control frequency current and to generate the auxiliary 3-kc frequency. The second tube is used to amplify the control and auxiliary frequency currents. The thermistor serves to control the power of the 3-kc frequency.

If the trunk line is very long (above 2,000 km) the use of automatic level control of the 2 types (flat and sloping) may be inadequate. This is explained by the possible accumulation of errors due to the deviations of the frequency characteristics of cable attenuation from a straight line. To compensate for the above errors, it is proposed to introduce a third level control, the so-called curvilinearity control, for which a third control frequency is required.

Remote Supply Installations

The K-12 system employs remote supply of the unattended amplification points, using a circuit consisting of 2 cable conductors, (over which the high frequency communication is also effected) and the ground. This circuit is produced by using the center taps of the line transformers as shown in Figure 10.

In the station which provides the remote supply, the voltage from the plate battery is applied to the center top of the line transformer through a carbon pile voltage regulator AVC_1, fuses, and a polarized signal relay R. In the supplied station the remotely-supplied voltage is applied from the center point of the line transformer to the winding of the switching relay R_3 and in parallel through contacts of this relay to the series-connected filaments of the tubes of both amplifiers of the 12-channel system.

The carbon pile regulator AVC_1 serves to maintain the remote-supply voltage constant. One end of the coil of its electromagnet is connected through the winding and contacts of relay R_{1-1} to the point at which the remote supply is fed. The second end of this coil is connected through contacts of relays R1-1 and R_{1-2} and through the winding of polarized signal relay R_{2-1} to the center tap of the line transformer of a separate pair in the cable, at which the center top of the line transformer is grounded at the supplied station. When so connected, the AVC_1 regulator compensates for the variations in cable conductor resistance, occurring through the entire amplifier sections as a result of temperature changes, and maintains constant the remote-supply voltage at the fed point.

If all the nonloaded cable pairs are used for carrier telephony, then the center points of the pair of loaded low-frequency group of 4 conductors is used for the electromagnet winding circuit. To prevent

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the d-c field of the supply current from magnetizing the loading coils of the phantom networks of the low-frequency pairs, the coil of the electromagnet of a second carbon pile regulator AVC_2 is connected to the center point of the transformer of the second pair of loaded group of 4 conductors.

If damage occurs to the circuits feeding the coil of the electromagnet of one of the carbon pile regulators, relays R_{1-1} and R_{1-2} disconnect the circuits of the electromagnet coils from the center points of the transformers of the loaded pairs, grounding them through resistors R_{2-1} and R_{2-2}, which equal to the average value of the resistance of the disconnected circuits. This prevents the magnetization of the loading coils of the phantom networks.

Polarized relays R and R_{2-1} are used to signal any change in the remote-supply current.

Relay R_3 in the supplied station insures automatic switching of the remote supply to a spare source (for example, to a second neighboring attended station) whenever damage occurs to the supply over the principal circuit. Protecting chokes Ch, connected if necessary in series with the filament supply circuit, serve to protect the latter from induced commercial frequency currents, which may occur in case of faults in high voltage lines that pass parallel to the communication cable line. One carbon pile regulator can serve up to 11 remote-supply circuits.

Entrance and Switching Installations

An entrance-switching rack (VKS) and an auxiliary testing and signalization cable line rack (SKT) are used for the entrance equipment of interurban cables.

The entrance switching rack is intended for connecting the interurban cable and also to protect the station equipment and the service personnel against dangerous voltages which may be induced in the cable. This rack permits replacing some pairs of cables by others and also to carry out control measurements over the cable. In addition to 4 boxes with terminal strips, which have shielded or nonshielded terminals, this rack carries the line transformers, the protective discharge gaps, and the induction coils. The latter are connected in the center-tap circuit of the line transformers and serve to increase the crosstalk attenuation between cable pairs. Cables with high and low levels (transmission and reception) are connected to different entrance-switching racks.

The VKS racks are mounted on porcelain insulators. The sheaths of the cables entering into the cable rack and the cable hangers are insulated from the ground. In addition, the racks to which low and high level cables are connected are insulated from each other. Rubber mats should be placed ahead of the VKS. The racks must be insulated from the ground so as to prevent possible cases of shock to the service personnel whenever high voltage occurs in the cable.

Mounted on the rack for cable-circuit test and signalization are the signalization elements that operate whenever the compressed air pressure in the cable drops, a set of relays for the service lines, and the conversation-calling installation. It is proposed in the future to mount on this rack a d-c bridge for cable measurements. The SKTS is also insulated from the ground.

Construction and Assembly of Apparatus -- Current Consumption

The K-12 apparatus is made up in the form of racks. Many of the racks have dimensions and constructions that are standard for all domestic long distance apparatus of most recent models. The majority of tacks can carry units for several 12-channel systems.

The terminal station is made up of the following racks: (1) tonal-calling rack STV, which provides room for 24 receivers and 3 tonal-calling generators; (2) differential system rack SDS, which can carry up to 108 differential systems (3 differential systems on each panel); (3) 4-wire switching rack SCHK, designed for mounting a measuring instrument (neper meter), conversation-calling installations, and 5 panels with 4-wire switching terminals and low-frequency amplification regulators, each panel serving 12 channels; (4) individual converter rack SIP, intended for mounting the individual frequency converter with the associated pass-band channel filters and low-frequency amplifiers, for one 12-channel system; (5) group installation rack SGU, on which are mounted the line amplifiers for transmission and reception, group frequency converters, and other elements of the group channel, and also ALC installations for 3 12-channel systems; (6) carrier and control frequency rack SNK, which can insure carrier and control frequency supply to 10 12-channel systems. All these racks measure 646 x 2,500 x 450 mm.

In addition to the above racks, the terminal station contains the following.

1. Remote supply transmission rack SDF-1, having a capacity of 22 circuits; its dimensions are 526 x 2,500 x 450 mm.

2. Entrance-switching rack VKS. A rack of this type is designed for installation of 4 boxes each having 2 terminal boards. The capacitance of the terminal strip with shielded terminals is 6 pairs of cables, and one without shielded terminals is 10 pairs of cables. The rack contains 64 positions for placement of transformers and inductance coils. The dimensions of the rack are 600 x 2,500 x 680 mm.

3. Cable circuit test and signalization rack SKTS. This rack is placed in the same row as the entrance-switching racks. The dimensions of the rack are 526 x 2,500 x 450 mm.

The intermediate amplifier stations are provided with intermediate amplifier racks SPU. If the SPU rack is installed in a station having automatic level control, then in addition to the line amplifiers this rack carries also the control-channel receivers. The capacity of each rack permits the mounting of equipment for 5 12-channel systems. The dimensions of the rack are 646 x 2,500 x 450 mm.

In addition to the intermediate amplifier racks, the attended intermediate stations, which provide power for remote supply, should also contain: (1) entrance-switching VKS racks whose number is determined by the capacity and purpose of the cables, (2) cable circuit test and signalization rack SKTS, and (3) remote supply transmission rack SDP-1 (Figure 11). The last 2 types of racks are not installed in remotely-fed unattended amplification points, which are provided only with remote supply reception racks SDP-II. The maximum capacity of the SDP-II rack is 20 circuits; its dimensions are 526 x 2,500 x 450 mm.

The current consumed by the K-12 apparatus for the supply of the filament and plate circuits of the tubes, as well as for the principal signal circuits, is shown in the table.

Name of Rack	Current Consuption amperes		Remarks
	filament battery	plate battery	
STV	2.90	0.11	for one 12-channel system
SChK	0.64	0.01	for one rack
SIP	1.90	0.085	for one 12-channel system
SGU	1.00	0.10	same
SNK	7.70	0.50	for one rack
SKTs	0.25	-	same
SPU with flat ALC	0.65	0.08	for one 12-channel system
same, with flat and sloping ALC	0.85	0.10	same
same, without ALC (remotely supplied)	-	0.12	same
same without ALC (locally supplied)	0.43	0.06	same

The nominal voltage of the source of filament supply is 24 v, and of the plate supply source is 220 v. However, for the SGU, SNK, and SPU racks with local supply it is necessary to stabilize the voltage of the supply sources with an accuracy of ±3%. The voltage at the output of the stabilizers will therefore be lower and may reach 21.2 ± 3% for the filament circuit and 206 ± 3% for the plate circuits. The remote supply is applied to the SPU rack from a plate voltage source with a nominal rating of 220 v, whereby the remote supply is stabilized, as was already indicated, with the aid of AVC regulators at the SDP-I rack. The STV and SIP racks can be fed, as in the V-12 apparatus, from stabilized or unstabilized sources of supply, with barreters used in the latter case for the filament circuits, thereby increasing the filament consumption by 33 percent as compared with the values indicated in the table.

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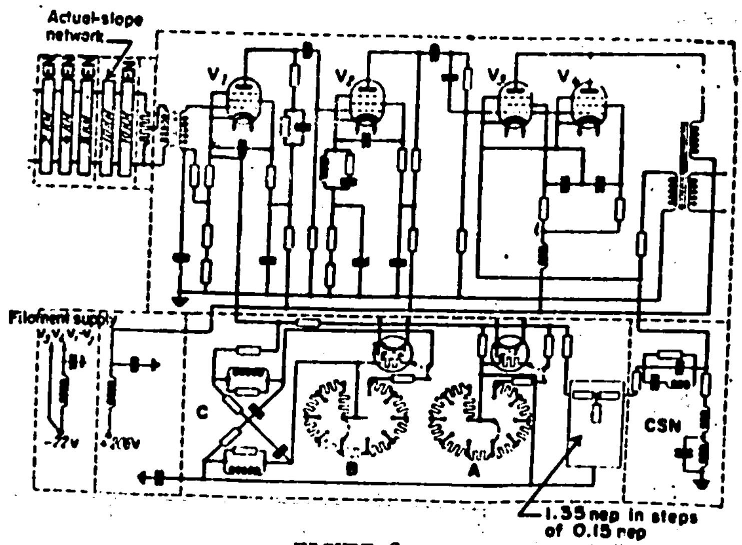

FIGURE 6

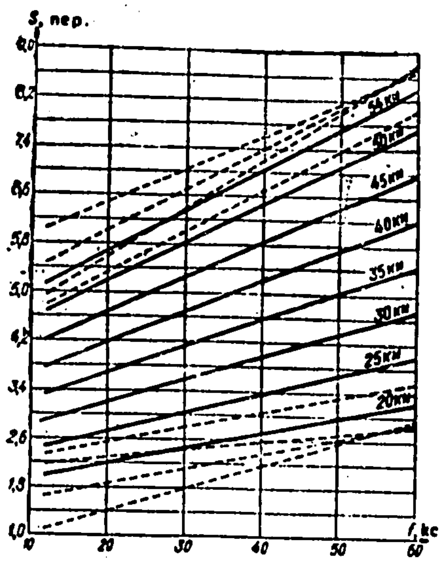

FIGURE 7

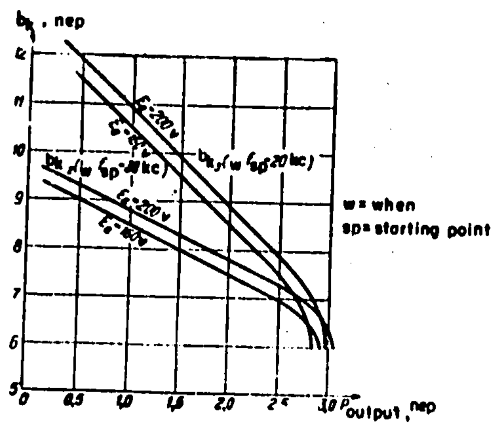

FIGURE 8

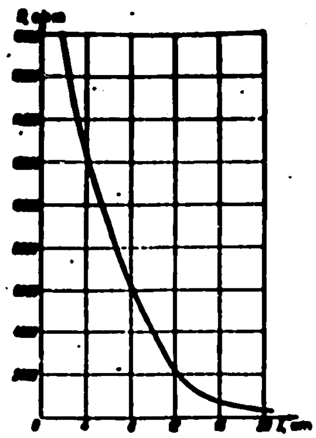

FIGURE 9

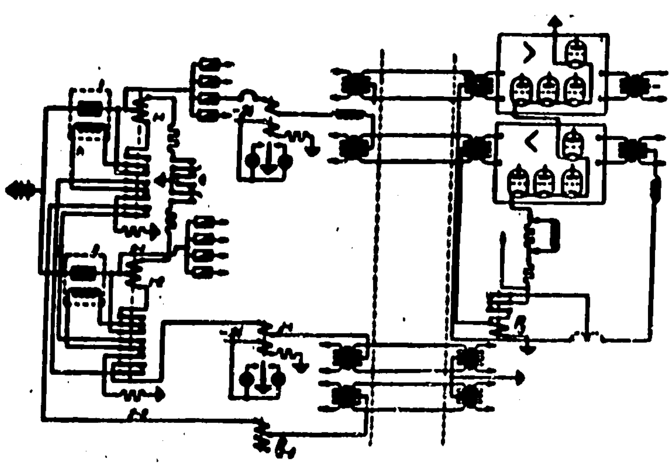

FIGURE 10

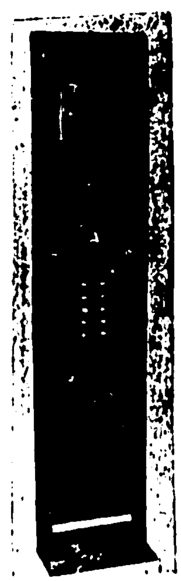

FIGURE 11

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