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Long-range H.F. Telephonic Communication over Power Transmission Lines

by
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[41a]

Consideration of the fundamental data of the EPO-1 apparatus, designed for the use of H.F. Telephony channels along electrical transmission lines. The method of single sideband transmission used in the apparatus and a number of other refinements permit a considerable increase in the range of H.F. communications, reliability and capacity [degree of use] of high voltage lines for telephonic purposes.

Introduction In 1922 Academician A.A. CHERNYSHEV carried out H.F. telephonic communication over the 110KV transmission line from KASHIR to MOSCOW. Later thanks to the work of V.A. D'YAKOV, A.M. KRUGLYAKOV, V.I. IVANOV, M.P. PANTIN and a number of other Soviet scientists and engineers this form of communication became the most important means of signalling [DISPETCHERSKOYE UPRAVLENIYE] on power systems.

The soviet apparatus type DPK, which works by transmitting currents at carrier frequency to line with two side bands and transmitter power of 5 watts on telephony, has been most widely used.

The rapid growth of power systems in the postwar period, the increase in distances over which electrical power is transmitted and the necessity for a considerable increase in the number of channels for both telephony and remote-control [telemechanics] and protection, all demanded the development of new types of H.F. apparatus.

This work was initiated by the communications laboratory of TSNIEL MES in 1945. Models of terminal apparatus for telephonic channels were worked out by the factory of the Ministry of the Communications Apparatus Industry in co-operation with the chair of long-distance communications of the Electrotechnical Institute of Communications i/n. BONCH-BRUYEVICH with participation by TSNIEL. The new apparatus was allotted the designation EPO-1 (communications over electrical transmission lines, single sideband, one telephonic channel /ELEKTROPEREDACHA ODNOPOLOSNAYA 7).

Conditions for Communications over Electrical Transmission Lines

For long distance communications over 110 or 220KV electrical transmission lines currents are used with frequencies from 50 to 300 Kc/s Transition / PEREKHODNYE 7 attenuations between individual transmission lines carrying H.F. currents are not large. For lines leaving a general / ?average 7 substation with the apparatus connected according to the phase-earth method, the transition attenuation is about 2 rep. In view of this, for communications over different lines it is necessary to use different frequency bands; duplication / repetition 7 of frequencies on the lines of a single power system is admissible only in exceptional cases.

Catering for all the growing demands of power systems for channels for telephonic communication, protection and remote control is possible only if
/41G 7 the most economical use is made of the frequency spectrum. This consideration is of the greatest importance in planning communication over electrical transmission lines.

A second and no less material feature of electrical transmission lines considered as lines of communication is the extremely high interference level due to corona effect, discharge at insulators and various transition / PEREKHODNY 7 processes. On 110KV lines the interference level in a band 2.5 Kc/s wide is -4.85 nep., and for 220KV lines, -2.85 nep.

Present day communications technique has many methods of modulation and detection. The most ecor mical frequency band, whilst preserving a relatively high degree of freedom from interference is obtained by the method by which current is passed to the line on only one side band in amptitude modulation; the current on the other side band and the carrier current are suppressed in the frequency changer and filters. This method was adopted as the principle in planning the EPO-1 apparatus.

Comparison of the EPO-1 apparatus with sets of types DPK, A.24 and others working on the principle of transmitting the currents of the carrier frequency and both sidebands to line shows that the change to the single sideband system, with the same degree of interference, allows for increase in line attenuation by 1.05-1.32 nep, corresponding to a gain in transmitter power of 8-14 times (depending on the depth of modulation in the old systems).

In Fig. 1. is shown the skeleton circuit of the H.F. channel. The attenuation on the length of line was determined by the approximate formula.

$$b = lk\sqrt{f} + 0.8n + 0.6\varepsilon + \beta_k l_k \qquad (1)$$

where l is the overall length of the electrical transmission line, in km; $K = 1.3 \times 10^{-3}$ for 110KV lines and 0.72×10^{-3} for 220 lines; f = frequency in Kc/s; n = number of by pass circuits; l_k the overall length of H.F. cable to the transmitting terminal and in all the by pass circuits (usually about 0.5 Km) β_k = damping per km. of cable (from 0.142 to 0.445 nep/km. in the band from 50 to 300 kc/s).

For a frequency of 150 Kc/s the attenuation of the H.F. circuit on
[42a] 110KV lines 200 Km. long with two by pass circuits is about 5.5 nep. and on 220 KV lines 300 Km. long with one by pass circuit, about 4.2 nep.

If we take 200 KV lines as a basis, and in accordance with what has been said above regarding interference level, assume this to be 2.85 nep; then satisfying ourselves with a safety margin [protection, shielding] of 3 nep. (operational tests show that the quality of reception of speech is better at this value), we obtain a transmitting level at the input of the H.F. section equal to + 4.35 nep., which corresponds to a transmitter power with single sideband apparatus of 6 watts. The necessity of working on frequencies up to 300 kc/s forces us to increase the power of the transmitter to 9-10 watts.

High frequency channels on electric transmission lines should not be put out of adjustment by damage to the line. Thanks to the presence between phases of electromagnetic linkage, the attenuation of the H.F. transmission circuit [track] in most cases of damage increases by 2-3 nep. Since when damage occurs the high voltage is taken off the transmission line and the interference level is considerably reduced, communications can work uninteruptedly, provided the apparatus is fitted with sufficiently good automatic regulation of amplification.

The Frequency band of the Apparatus: The EPO-1 apparatus works on a band of frequencies from 51 to 303 Kc/s. This range is subdivided into 84 bands each 3 Kc/s broad. 51-54 Kc/s, 54-57 Kc/s and so on to 300-303 Kc/s. To obtain a two-way telephonic conversation any two bands of 3 Kc/s width can be used provided that they are separated by not less than 12 Kc/s. The tuning of the apparatus is fixed, but provision is made for mutual changes of the positions of the transmitting and receiving frequency bands. The band of frequencies which can be effectively transmitted in the audible /_tonal_7 range lies within the limits of from 0.3 to 2.7 Kc/s.

The conversion of the speech frequencies takes place in two stages. In the first stage carrier frequencies of 6, 9, 12, 15 Kc/s can be used. As a result of the first conversion the speech frequencies are transferred to the bands 3-6, 6-9, 9-12 and 12-15 Kc/s.

By means of a second conversion the speech frequency band is transferred to the position in the frequency spectrum 51-303 Kc/s which it is to occupy on the line. In the second stage of the conversion carrier frequencies
/_42b_7 66, 78, 108, 120, 150, 162, 192, 204, 234, 246, 276 and 288 Kc/s are used At the output from the converter either the upper or lower side band is removed by the band filter. The choice of nominal carrier frequencies in two stage conversion is made according to what frequency bands are to be used on the line. In the receiving part of the apparatus frequency conversion takes place in the reverse order. The distribution of frequencies of the EPO-1 apparatus is given in the table.

Crystal frequency Kc/s	Channel No.
66	1, 2, 3, 4, 7, 8, 9, 10
78	5, 6, 7, 8, 11, 12, 13, 14
108	15, 16, 17, 18, 21, 22, 23, 24
120	19, 20, 21, 22, 25, 26, 27, 28
150	29, 30, 31, 32, 35, 36, 37, 38
162	33, 34, 35, 36, 39, 40, 41, 42
192	43, 44, 45, 46, 49, 50, 51, 52
204	47, 48, 49, 50, 53, 54, 55, 56
234	57, 58, 59, 60 63, 64, 65, 66
246	61, 62, 63, 64, 67, 68, 69, 70
276	71, 72, 73, 74, 77, 78, 79, 80
288	75, 76, 77, 78, 81, 82, 83, 84

Note Channel No.1 occupies the band from 51-54 Kc/s, channel No.2 from 54-57 Kc/s &c. up to channel No.84 which occupies the band from 300-303 Kc/s.

Standardisation of the positions of the sidebands was introduced for the first time in communication over electrical transmission lines. This refinement allows a substantial improvement to be made in the organisation of communications on large power systems.

Skeleton Circuit of EPO-1 apparatus and transmission and reception levels.
The skeleton circuit of the EPO-1 apparatus is shown in Fig. 2.

Speech currents passing through the contact of the relay of the automatic selector [AVTOMATIKA] and through the 0.4 nep extender [UDLINITEL'] (which is switched out with two-wire working [TRANZIT]) reach the first-stage converter M.1 through the differential circuit DS. This converter like all the others, is assembled from cuprous oxide elements [KUPROKSY] in a bridge [ring] arrangement. Carrier currents of 6, 9, 12 or 15 Kc/s are fed from the harmonic generator GNCh with a fundamental frequency of 3 Kc/s, crystal controlled.

To the output of the first converter is connected the band-filter P.F., which removes the lower sidebands, (3-6, 6-9, 9-12, 12-15 Kc/s). The currents separated by the band-filter reach the second stage converter M.2 through the intermediate amplifier PUS. Carrier currents are supplied to it from the crystal generator KG-VCh, tuned to one of the 12 frequencies (see table).

Connected to the putput of converter M-2 is the band filter F_{per} which separates the sideband for transmission to the line. Passing through the filter F_{per} the currents are amplified by the high power transmitter amplifier MUS and reach the line via the line filter LF.

When a tone frequency of 800 c/s is applied to the input of the apparatus with a level of -1 nep, the level corresponding to the side-band frequency at the input to the line is + 4.6 nep (10 watts). Thanks to thishigh transmission level the difference between the signal level and mean interference level at the receiving end is not less than 3 nep. with attenuation on 220KV lines of up to 4.45 nep. and on 110KV lines up to
/43a_7 6.45 nep. The minimum reception level can be -3.4 nep., and this ensures, in an emergency, communications over lines with attenuation up to 8 nep.

Currents coming in from the line reach the receiving portion of the apparatus through the band filter P.F. and the extender U, the attenuation
/43b_7 of which can be regulated between the limits 0-5 nep. in steps of 0.5 nep. By means of the extender U a normal level of reception is established at the input of the controllable artificial line RIL. The total attenuation of the line and extender should be about 6 nep.

Fluctuations in line attenuation within the limits of ± 2 nep. are
/44a_7 automatically compensated by corresponding changes of the attenuation in RIL which can be regulated by the control current. For the latter, the carrier current from the first-stage converter is used, this being fed from GNCh to the intermediate amplifier PUS and the first converter in parallel. The level of the control current at the input to the line is + 3.1 nep.

Automatic control of the level is accomplished by changing the bias on the cuprous oxide rectifiers in the circuit of the RIL. Passing through RIL and the amplifier UPR the HF current reaches the first stage receiving converter D-1.

After the converter a low-frequency filter FO-15 which passes frequencies of up to 14.7 Kc/s, and an intermediate receiving amplifier PUS, are connected.

The control current receiver ARU is connected to the output of PUS: Direct current from the output of this receiver reaches RIL and controls its attenuation, in correspondence with changes in the level of the control current coming in from the line. To the ARU receiver is also connected the call signal receiver PR,VYZ to the output of which is connected the winding of the calling relay.

Speech currents through the bandfilter PF reach the second-stage converter D-2 and then via the low frequency filter FNCH, the low frequency amplifier UNCh, the differential system DS. and automatic sector to the subscriber.

/44b/ By means of UNCh the residual attenuation of the channel at 800 c/s is adjusted to a value of 0.8 nep. This amplifier also enables the frequency characteristic of the residual attenuation to be corrected. A number of the units of EPO-1, e.g. GNCh, UNCh some of the filters etc., are borrowed from the standard apparatus Type V-3* which simplifies industrial adoption of the EPO-1 apparatus.

The diagram for the levels throughout the transmitting and receiving stages of the EPO-1 apparatus is shown in Fig. 3.

Technical data of the separate units and characteristics of the EPO-1. The transmitter and receiver filters and also the line filter are constructed on the differential-bridge six-element scheme. In the transmitter section the filters are single-stage . The receiver filter is double-stage. The width of the band passed by the filters is 6 Kc/s. The attenuation of the band passed is from 0.25-0.3 nep. for one stage in the lower part of the range and up to 0.6 nep. in the upper part.

Attenuation characteristics of one of the filters is shown in Fig. 4.

In the filters for all channels a single inductance assembly is used. Tuning of the filters is accomplished by change of capacities.

The high power transmitter amplifier MUS produces a rise of level by 8.7 nep. Non-linearity in the frequency characteristic over the whole range does not exceed 0.05 nep. The first two stages of MUS with 6AS7 valves are resistance coupled voltage amplifiers. The third, output stage is a power amplifier working in a push-pull arrangement with P50 valves. The anode voltage on the MUS is applied only when the subscriber's receiver is lifted or after receipt of the calling signal and is cut off on ringing off.

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* V.N. AMARANTOV & G.V. STARITSYN. Three channel H.F. telephony apparatus Type V-3 SVYAZ'IZDAT 1950.

The characteristic of the residual attenuation of the channel is shown in Fig. 5. The regulation curve of the channel showing the change in the level at the output of the receiver portion of the apparatus on changing the attenuation of the line from 4 to 8.5 nep. is shown in Fig. 6

Automatic Selector and current supply to EPO-1 apparatus

The automatic selector of the EPO-1 apparatus gives automatic selective calling of subscribers connected to the H.F. communication channel on electrical transmission lines. Subscribers enjoy the same convenience and simplicity in using the line as do subscribers of an automatic telephone exchange.

All subscribers connected to one communication channel have numbers from 0-9 so that they can be called by selection of a single figure. One of these numbers is allotted to the distributing / PEREPRIYEMNY / apparatus. In calling a subscriber on a neighbouring channel two figures are selected: the number of the distributing apparatus and the number of the subscriber on the neighbouring channel. In calling a subscriber connected through one channel three figures are selected and so on.

Three subscribers can be connected to a terminal EPO-1 apparatus and these may be, normally, automatic telephone exchange apparatuses or switchboards or instruments for 4-wire automatic distribution / pass-on /. In the last case special sets of telephone relays are provided and these can either be mounted in the apparatus itself or outside it.

The above mentioned functions are carried out by the automatic selector consisting of 35 type RM relays, two polarised relays type RP-5 and a selector / searcher / type ShI-11. The set of relays for each subscriber consists of 3 relays. The polarised relays are used for manipulating the control frequency in the transmitter and for reception of calling signals, selection of numbers and ringing off at the receiver.

In the quiescent state the transmitter is switched off, the control frequency output into the line / transmission tract / is shortcircuited by the contacts of the polarised relay and the receiver is in the state of maximum sensitivity.

When one of the subscribers lifts his receiver a channel is engaged by transmission of the control frequency to line by the transmitter of the calling apparatus. In the receivers of the called apparatus automatic adjustment of the level occurs and the polarised receiving relay operates, completing / preparing / the circuit / which produces / the audible "engaged" signal. The calling subscriber receives the "ready" signal for
/45b/ dialling / "selecting the number" /. Selection of the number takes place by interrupting the transmission of the control frequency by means of the polarised relay in the transmitting section. During dialling of the number the working of the automatic level control (ARU) is not disturbed, since the corresponding regulation of time constants gives automatic level control / ARU / independent of the dialling pulses.

After selection of the number the transmitter of the instrument called is switched on and a calling signal (AC at 50 c/s) is sent to the subscriber. At the same time the calling subscriber receives an audible control-calling signal which ceases when the subscriber called lifts his receiver. After the call, on ringing off, transmission of control frequency to line ceases i.e. the channel is completely freed (both ends ringing off). If the subscriber does not replace his receiver he is blocked and hears the audible ringing-off signal.

All the service audible signals are produced by transmitting to the subscriber an audible frequency over the same pair of wires are as used for conversation.

To check the working of the automatic selector in the EPO-1 a special checking-calling panel is provided consisting of a telephone set TsB-MB and a switch panel. The telephone set can be switched in either to the apparatus instead of one of the subscribers or to any of them for checking the line. By using the sockets on the switchboard, the line of any subscriber may be connected, the low frequency differential system can be completely disconnected, the input to the transmitter and the output of the receiver can be connected to separate leads.

/46a_7 Mounted on the switchboard is the relay which switches the transmitter input and receiver output to the four-wire system for automatic relaying. Provision is made in the automatic selector for connecting the relaying arrangement, this consisting of two relays in each direction in which relaying occurs.

The arrangement for emergency signalling regarding failure of the DC supply voltages of 24, 220 and 450 V, consists of three type RM relays. The signals are given on a lamp panel and over the external signal system and is supplied from an independent source.

Supply to all the relays and automatic selectors is from a 24V selenium rectifier. The load current is up to 1.5-1.75a. Supply to the microphones of the subscribers apparatus is from a separate 48V selenium rectifier via the windings of the subscriber's relay. All voltages, D.C. and A.C., required for the working of the EPO-1 are obtained from the power unit mounted in the lower part of the rack. 50 c/s A.C. at 110, 127 or
/46b_7 220 volts is supplied to the power unit. Thanks to the use of ferro-resonance stabilisers the permissible voltage fluctuation on the mains lies within the limits -20 to + 10%. The power drawn from the mains is about 700 watts.

<u>Construction</u>. All the equipment of the EPO-1 apparatus is disposed on standard racks measuring 2500 x 650 x 400 mm. The construction of all circuits except the power unit, MUS and ATS /automatic telephone exchange_7 is on the block system. A general view of the apparatus is shown in Fig. 7.

<u>Line Tests</u>: The EPO-1 apparatus has been tested on 220 KV lines over 207 km. With the chosen tuning frequencies of 231 and 255 Kc/s the attenuation of the communication channel was 41-45 nep. The level of line interference with a 2.5 Kc/s band width was from -3.0 to -2.2 nep. Besides the EPO-1 apparatus there were connected to the communications / ? line_/ condensers telemechanical sets working on 165 and 281 Kc/s; there was no interchannel effect. The tests gave positive results as regards quality of transmission of speech and reliability of communication.

Experimental models of EPO-1 have been put into constant operation.

19.10.51.

Figure Captions

Fig. 1: Skeleton circuit of a H.F. Channel. 1: Terminal station 2: H.F. cable. 3: Connecting filter. 4: ?Coupling/line/communications condenser / KONDENSATOR SVYAZI /. 5: H.F. Stopper. 6: By pass circuit.

Fig. 2: Skeleton circuit of EPO-1.

Fig. 3: Levels diagram for EPO-1 apparatus.

Fig. 4: Attenuation curve of (1) single stage and (2) double stage transmitting and receiving filters.

Fig. 5: Residual attenuation curve for channel $P_{Bx} = -1.0$ nep.

Fig. 6: Regulation curve for channel.

Fig. 7: General view of EPO-1 apparatus.

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Fig. 1

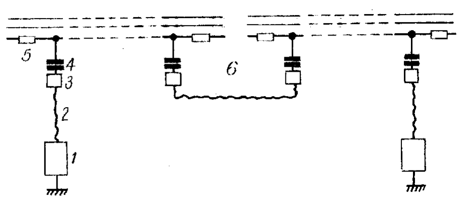

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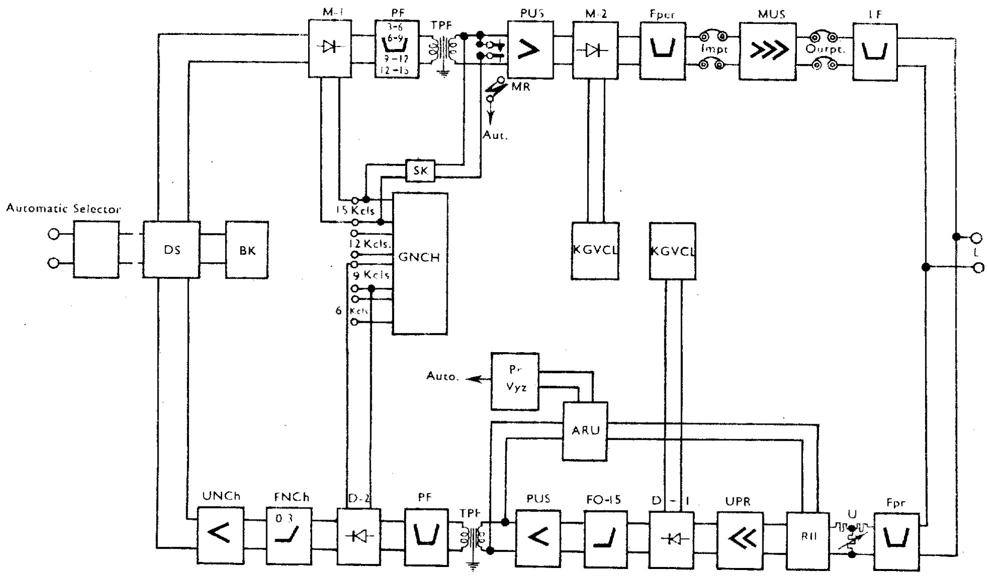
Fig. 2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Aut.
SK
15 Kcls
12 Kcls.
9 Kcls
6 Kcls
GNCH
Automatic Selector
DS
BK
KGVCL
KGVCL
L
P-
Vyz
Auto.
ARU
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U
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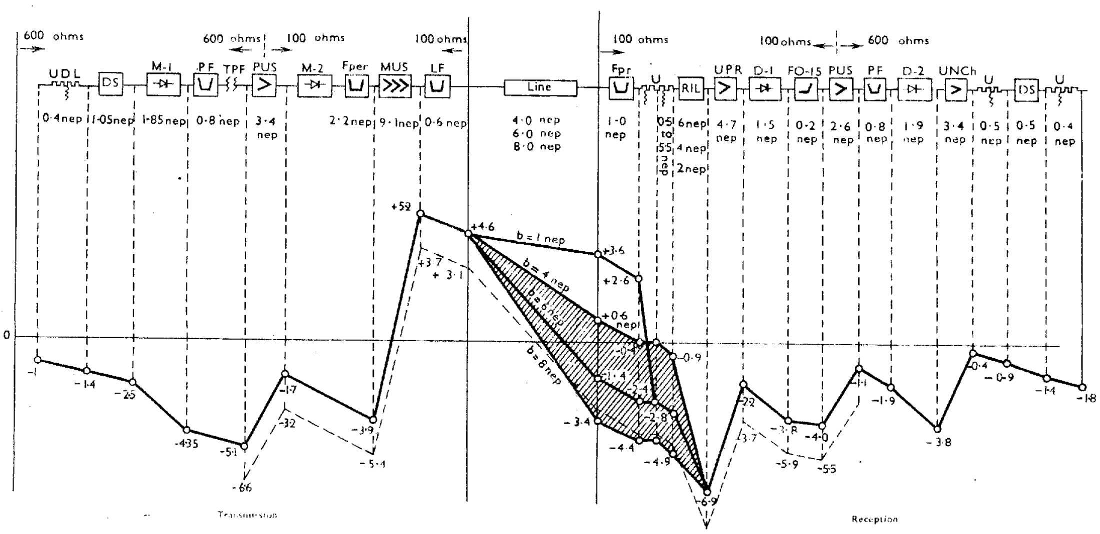
Fig. 3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Fper
MUS
LF
Line
Fpr
U
RIL
UPR
D-1
FO-15
PUS
PF
D-2
UNCh
U
DS
U
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1·05 nep
1·85 nep
0·8 nep
3·4 nep
2·2 nep
9·1 nep
0·6 nep
4·0 nep
6·0 nep
8·0 nep
1·0 nep
0·5 to 5·5 nep
6 nep
4 nep
2 nep
4·7 nep
1·5 nep
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3·4 nep
0·5 nep
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Transmission
Reception

Fig. 4

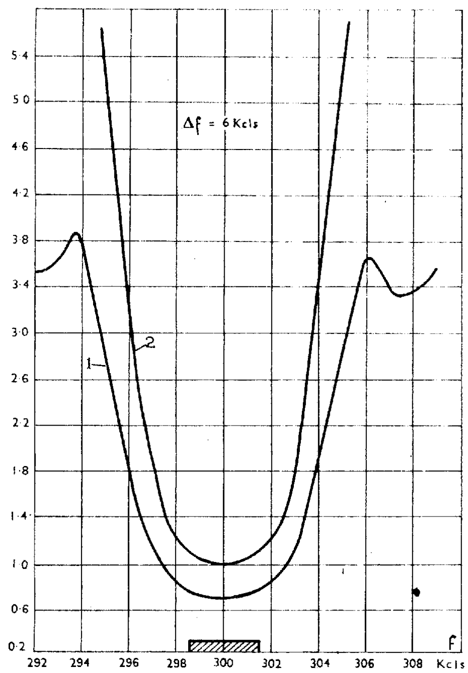


Fig. 5

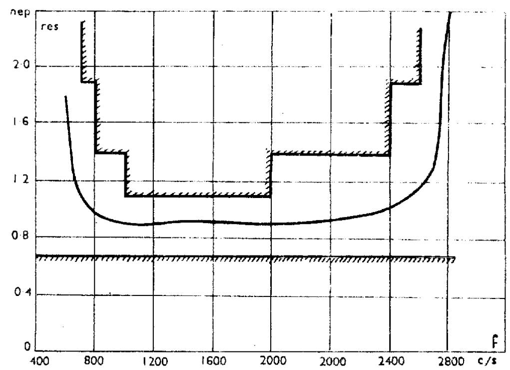
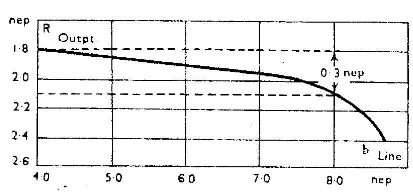


Fig. 6



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