CONFIDENTIAL

RESEARCH DEPARTMENT

The C. B. S. 'Audimax II RZ' automatic control amplifier

TECHNOLOGICAL REPORT No. L-068

UDC 534·86: 621·395: 665·1 1966/42

THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

RESEARCH DEPARTMENT

THE C.B.S. 'AUDIMAX II RZ' AUTOMATIC CONTROL AMPLIFIER

Technological Report No. L-068
UDC 534.86: 1966/42
621.395.665.1

D.W. Stebbings, B.A.

D.Maurice
for Head of Research Department

This Report uses SI units in accordance with B.S. document PD 5686.

Technological Report No. L-068

THE C.B.S. 'AUDIMAX II RZ' AUTOMATIC CONTROL AMPLIFIER

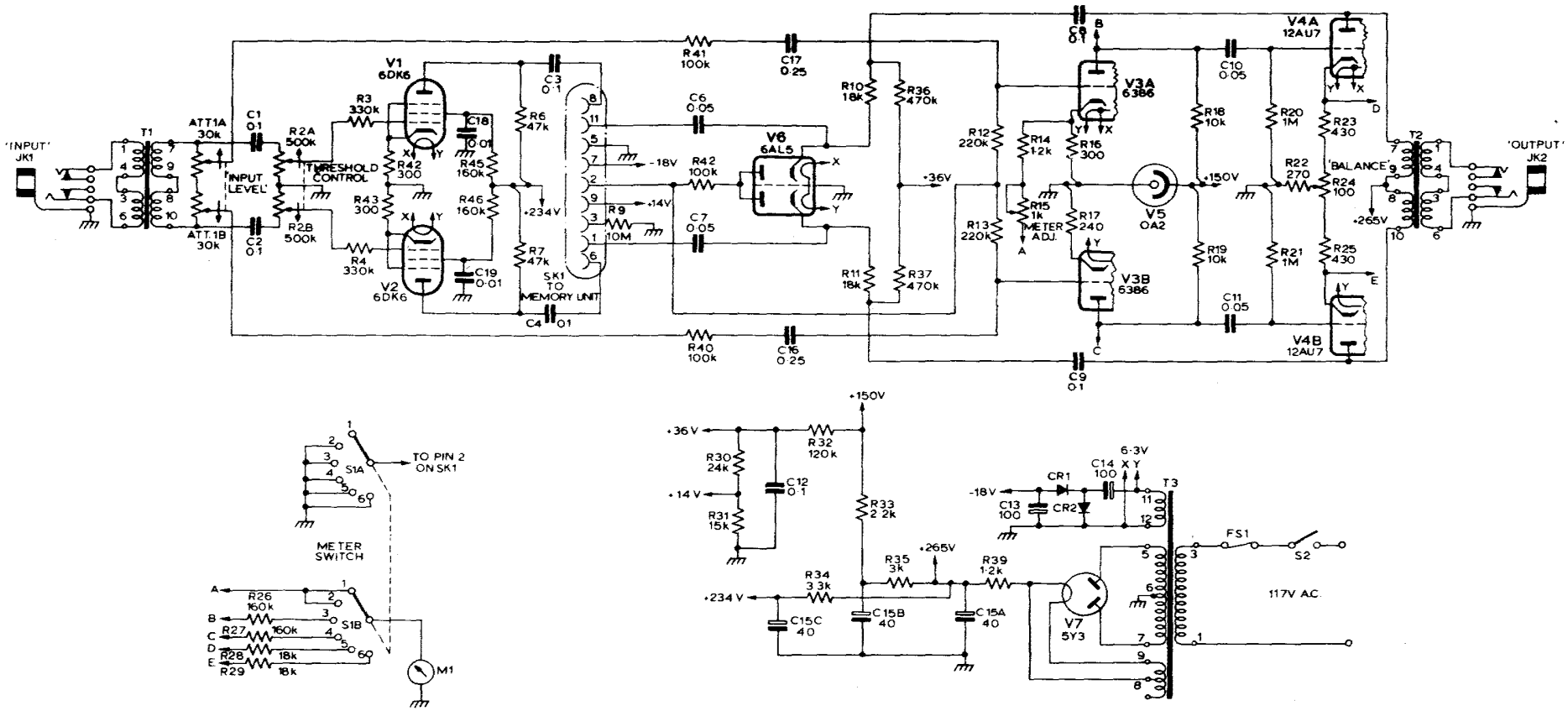


Fig. 1 - "Audimax II RZ" amplifier : circuit diagram

August 1966

Technological Report No. L-068
UDC 534.86: 1966/42
621.395.665.1

THE C.B.S. 'AUDIMAX II RZ' AUTOMATIC CONTROL AMPLIFIER

SUMMARY

The "Audimax II RZ" is an automatic gain control amplifier produced by the Columbia Broadcasting System in the U.S.A. It is intended to reduce the need for manual control of signal levels at a studio and also to raise the mean signal level as far as is possible without introducing impairments to the technical or aesthetic quality of the programme.

The device is effective on many types of programme material provided that the initial dynamic range is not too great; in other cases, the controls need to be adjusted according to the nature of the item. Non-linear distortion is audible on most items; this defect could possibly be eliminated by improved circuit design.

1. INTRODUCTION

The Columbia Broadcasting System (C.B.S.) "Audimax II RZ" is a device designed to compress the dynamic range of programme level to within prescribed limits while minimising the faults commonly associated with automatic gain control amplifiers, particularly "gain pumping" and accentuation of background noise. The equipment has a longer attack time than is usual in volume compressors and thus requires to be followed by a quick-acting limiter.

During loud passages of programme the action of the "Audimax" gain control amplifier is like that of a limiter having rather long operate and return times, arranged to effect about 8 dB of compression. In sustained quiet passages, however, up to 10 dB of gain is introduced over a period of several seconds, but this additional gain is not maintained during prolonged pauses in the programme, the system returning to normal after five- to ten-second interval. By this means a total maximum compression of some 18 dB is achieved without the disadvantage of giving undue prominence to background noise or interference.

The price, to the BBC, of the "Audimax II RZ" amplifier in 1965 was £229.

2. DESCRIPTION

The circuit of the "Audimax" amplifier is shown in Fig. 1. T.1 is the input transformer which provides anti-phase outputs feeding the grids of the pushpull variable-mu valves V3-A and B via input attenuators Att.1-A and B. The variable-gain stage is coupled to the output amplifier valves V4-A and B which drive the output transformer T.2. Series feedback in the form of un-decoupled cathode resistors is applied to each stage. The control voltage to the variable-gain stage originates in a plug-in, encapsulated container described by C.B.S. as a "memory unit". The circuit details of the unit are not supplied but it probably contains several semiconductors.

The memory unit has four input terminals. The first of these is supplied with signals derived from the amplifier input via potentiometers R2-A and B and pushpull amplifiers V1 and V2. The setting of potentiometer R2-A and B determines the lowest level of programme that can influence the control circuit. The second terminal receives a voltage derived from the anodes of V4-A and B and rectified by the double diode V6. The third and fourth terminals are supplied with D.C. reference voltages.

The scale of the meter M1 is calibrated in dB and indicates the gain of the amplifier up to ±10 dB from a centre zero. The zero represents the gain of the amplifier when in the quiescent state of no input signal. In four positions of the six-way switch, S1, the meter is utilised to check D.C. voltages at various points in the circuit; in the fifth position the amplifier and meter are connected for normal operation, and in the last position the variable-gain action is removed enabling the original programme to be monitored uncontrolled.

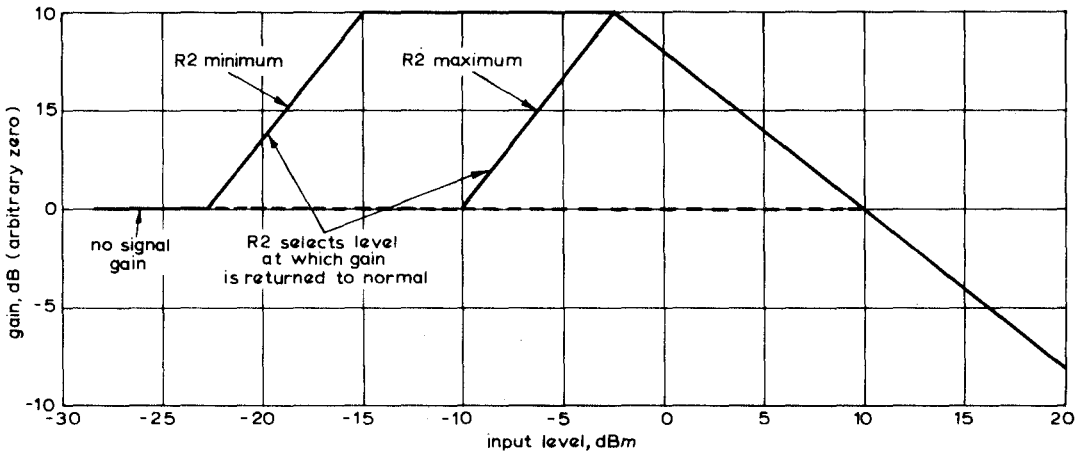


Fig. 2 - "Audimax II RZ" amplifier : variation of gain with input level under steady-state conditions (diagrammatic form)

2.1. Mode of Operation

The operation of the amplifier can be explained with reference to Fig. 2, which shows in diagrammatic form the steady-state gain of the device as a function of input level. The "Audimax" amplifier differs from conventional limiters used as compressors in that on cessation of the input signal it does not return to its maximum gain.

With a tone input at +10 dBm*, the gain of the system is equal to the quiescent or no-signal value. With increasing input level up to +20 dBm - the maximum for which the amplifier is designed - the gain is automatically reduced, as in a limiter, so that the output level rises only slightly. Conversely, with reduction of input level from +10 dBm to to -2 dBm, the gain of the amplifier is raised by about 10 dB, again holding the output level nearly constant. In this way a total gain reduction of some 18 dB can be obtained. The arrival of an input signal having a level lower than -2 dBm results in either a return to the normal gain of 0 dB or a continuation of the value of +10 dB according to the level applied and the setting of R2; Fig. 2 shows the range of variation possible. The minimum input signal which will operate the control chain, and thus alter the gain of the amplifier, varies from -10 dBm to -22 dBm according to the setting of R2.

If programme ceases when the amplifier is in the position of maximum sensitivity, the gain returns to normal after a delay of from 5 to 10 seconds.

3. STATIC CHARACTERISTICS

3.1. Output/Input Characteristics

Fig. 3 illustrates the measured steady-state output/input characteristic for various settings of R2 with the input level control set at maximum. The gain of the amplifier was allowed to stabilise before each measurement was taken. For input levels above -3 dBm, the compression ratio, measured by the inverse slope of the output/input characteristic, is about 7 : 1, intermediate between the figure of 2 : 1 common in conventional compressors and the 20 : 1 more usual with limiters.

3.2. Frequency Characteristic

The frequency characteristic of the programme and control chains was measured for an input level of +10 dBm, i.e. a reading of zero on meter M1. The frequency characteristic of the programme chain was measured by varying the input signal to produce constant side-chain control voltage (measured at pin 2 of V3-A) and then recording the difference between the amplifier input and output signals. The result is shown in Fig. 4; from 20 Hz (c/s) to 20 kHz (kc/s) the curve is uniform within +0·1 dB to -0·5 dB relative to the level at 1 kc/s. The control chain frequency characteristic was determined by measuring the variation in input signal required to keep the reading on M1 constant. Since an increase in input implies a decrease in control chain sensitivity, the inverse of the curve obtained is the required frequency characteristic and this is shown in Fig. 5. The variation in the shape of the curve as a function of signal level was less than ± 0·1 dB.

3.3. Noise

The unweighted r.m.s. noise output of the amplifier (measured after the gain had returned to the no-signal value) was 81 dB below peak level output.

3.4. Distortion

The total non-linear distortion of a 1 kHz (kc/s) tone measured at an output level of +22·5 dBm was 1·4%. There was no evidence on an oscilloscope of clipping of the signal waveform by the diodes V6.

* decibels above 1 mW.

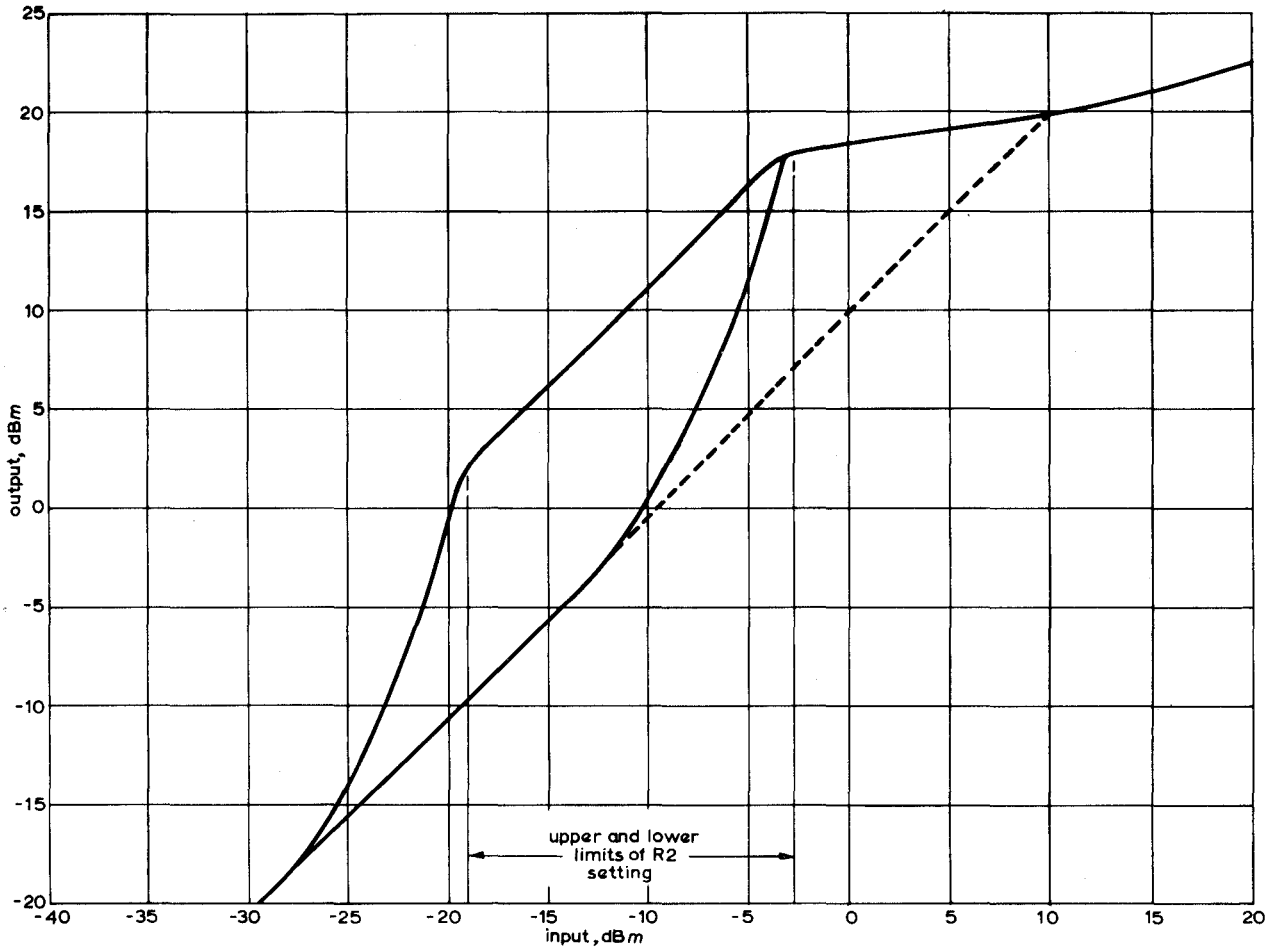


Fig. 3 - "Audimax II RZ" amplifier : output/input characteristic under steady-state conditions

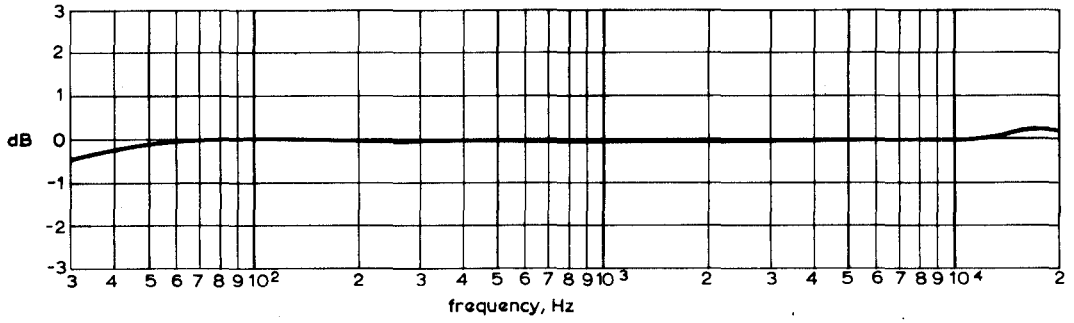


Fig. 4 - "Audimax II RZ" amplifier : frequency characteristic of programme chain

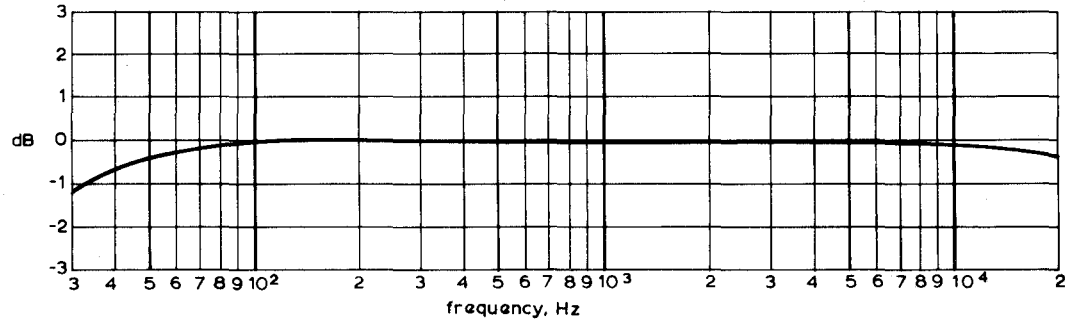


Fig. 5 - "Audimax II RZ" amplifier : frequency characteristic of control chain

3.5. Input and Output Impedances

Tables 1 and 2 show respectively the modulus of the input and output impedances, measured at a level of +10 dBm; the nominal value in each case is 600 ohms.

TABLE 1

Input Impedance

Frequency, Hz (c/s)	20	100	1k	10k	15k
Impedance, ohms	600	610	620	490	345

TABLE 2

Output Impedance

Frequency, Hz (c/s)	20	100	1k	10k	15k
Impedance, ohms	460	480	490	450	360

4. DYNAMIC CHARACTERISTICS

4.1. Attack Characteristics

The attack characteristics of the "Audimax" amplifier were assessed both by the sudden application of a signal and by a sudden increase in level of the signal already present.

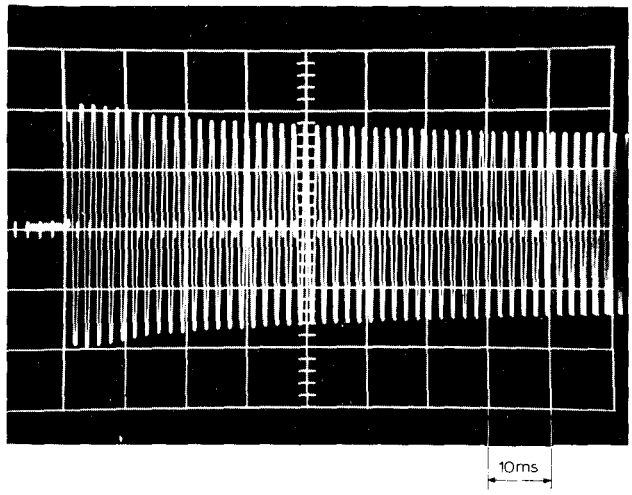
In the first case a switched 500 Hz (c/s) tone of input level +20 dBm was applied, giving 8 dB gain reduction. Fig. 6(*a*) shows an oscillogram of the resulting output voltage. Because of overloading in the output stage, the tone is clipped for the first few cycles so that the waveform envelope does not exhibit the expected overshoot.

In the second case, shown in Fig. 6(*b*), to enable the distortion due to clipping to be more easily observed, a frequency of 110 Hz (c/s) was chosen for the applied tone and was switched from 0 dBm to +20 dBm, giving a gain reduction of 16 dB. The distortion persists for approximately 30 ms. Evidently the gain reduction takes place more slowly than would be expected from the attack time of 10 ms quoted by C.B.S.; the latter figure is about six times as long as the attack time of the limiter LIM/6 currently in use in the Corporation. The slow gain reduction of the "Audimax" amplifier is partly attributable to the fact that the control signal is derived from the output stage which, as already indicated, restricts the crest value of the excess signal.

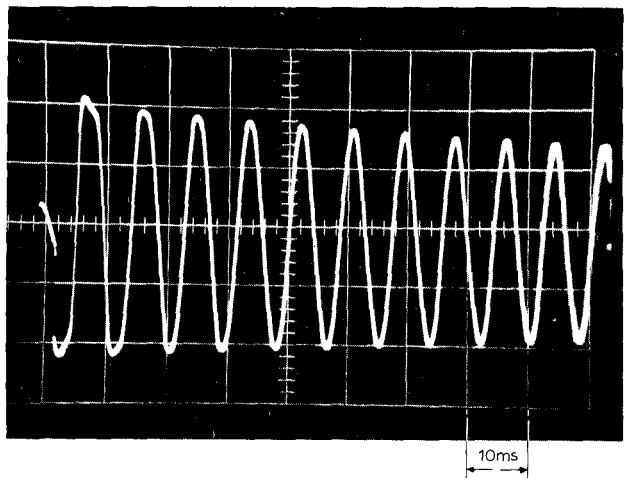
4.2. Recovery Characteristics

The recovery time of the amplifier varies with input level and the state of the amplifier when that level is applied. The time taken for the gain to stabilise when the input varied between +22 dBm to +10 dBm (-10 to zero on the meter) was measured by suddenly switching the level of the input tone from the higher to the lower value and observing the subsequent rise in output. The recovery time, taken arbitrarily as the interval between the instant of switching and the moment when the signal was 2 dB below its final level, was 3·8 seconds, which is an order greater than that of a conventional syllabic compressor. On switching the input from +10 dBm to 0 dBm the corresponding time was 7·5 seconds.

When the input signal level was reduced below the minimum value required to operate the control chain, the gain of the amplifier remained constant for 10 seconds, returning to the quiescent value over a further period of 10 seconds.



(*a*)



(*b*)

Fig. 6 - "Audimax II RZ" amplifier : oscillogram of output with

(*a*) input at 500 c/s + 20 dBm suddenly applied
(*b*) input at 110 c/s increased suddenly from 0 dBm to +20 dBm

5. PROGRAMME LEVEL ANALYSIS

A passage of programme was used to assess the effect of the "Audimax" amplifier on the statistical distribution of signal amplitudes. An excerpt from an interview having a large dynamic range was chosen in which the signal level of one voice, as indicated on a peak programme meter, was some 15 dB higher than that of the other. The distribution of levels was analysed in 2 dB steps from -24 dBm to about +10 dBm by an automatic device[1] which sampled the P.P.M. current five times per second. For the sake of clarity, the two voices were sampled separately and Fig. 7 shows the histograms obtained from the original excerpt. It will be seen that the difference between the modal values for the two voices is about 14 dB; the standard deviation is 5 dB and 4 dB for the quiet and loud voices respectively.

The programme was then analysed after passage through the "Audimax" amplifier. In accordance with the manufacturers' instructions, the amplifier was followed by a quick-acting limiter, in this case type LIM/6, and the output level was adjusted so that with a tone input representing peak programme level applied to the system the gain of the LIM/6 was reduced by 6 dB. The resulting distribution of levels is shown in Fig. 8. It can be seen by comparison with Fig. 7 that the modal value of the quieter voice has been raised by about 12 dB; the standard deviation is 3 dB and and 2½ dB for the quiet and loud voices respectively. For comparison purposes the test was repeated with a BBC limiter type LIM/6 and a 2 : 1 compressor, each adjusted to give a maximum gain reduction of 12 dB, the value currently used on programme transmitted by the BBC medium wave service. The attack time of both these devices was approximately 1·5 ms; the recovery times were 0·5 second and 0·1 second for the limiter and compressor respectively. Figs. 9 and 10 show the histograms obtained. Table 3 summarizes the principal conclusions to be drawn from the level analyses.

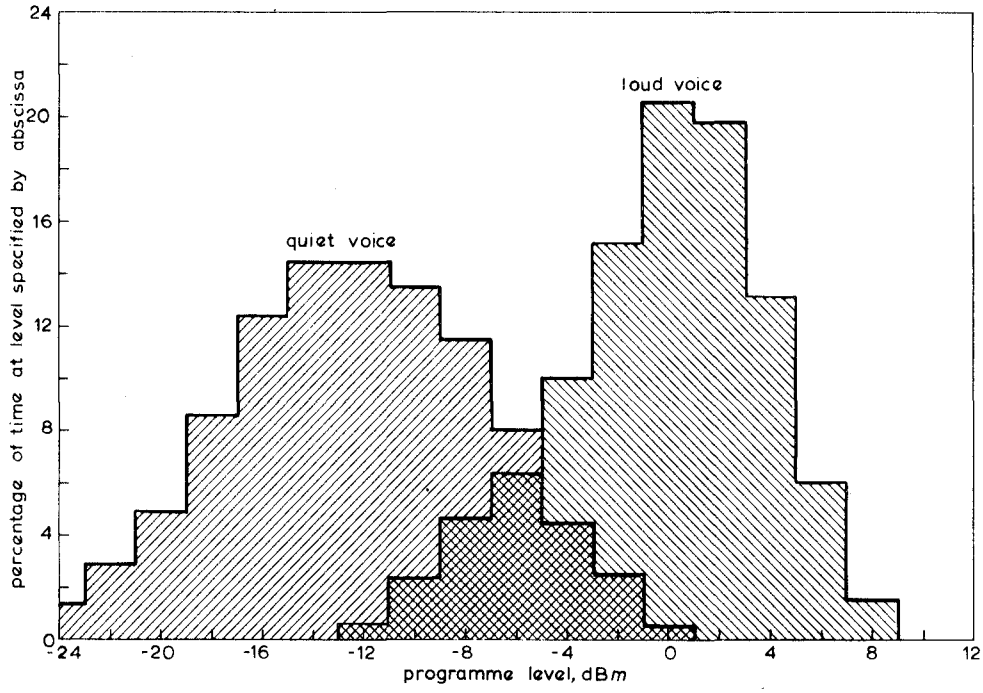


Fig. 7 - Histograms showing level distribution of two voices in interview : original programme

TABLE 3

	Original	Audimax + Limiter	Limiter as Compressor	2 : 1 Compressor
	dB	dB	dB	dB
Standard deviation: quiet voice	5	3	3½	4
Standard deviation: loud voice	4	2½	2½	3
Difference between modal values	14	2	4	5

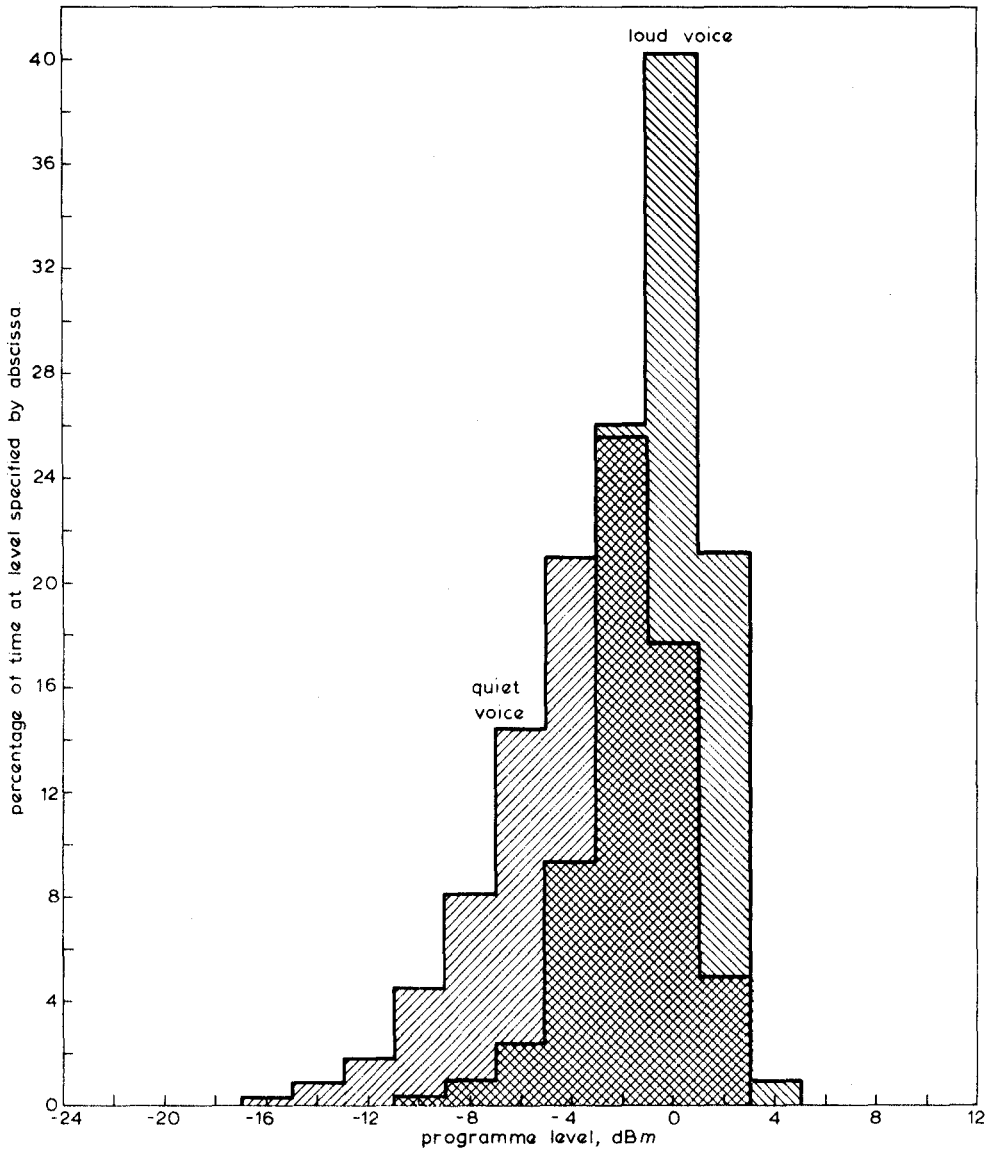


Fig. 8 - Level distribution of voices after passage through "Audimax II RZ" amplifier

It will be seen that the "Audimax" amplifier is more effective than either of the other two devices in reducing the disparity in level between the two voices in the interview and in restricting the level range covered by each voice.

6. SUBJECTIVE TESTS

Listening tests were carried out on a variety of programme material, including a number of selected items likely to reveal defects in automatic gain control devices.

In general, the quality of reproduction gave a favourable impression. "Gain pumping" and accentuation of background noise were less evident than with conventional compression devices operating at syllabic rates, while choral music was less subject to flutter effects due to rapid gain fluctuation. On the other hand, in a quiet passage of programme following a loud passage, the rise of gain in the "Audimax" amplifier was spread over a number of seconds, giving the impression of a somewhat tardily operated manual control.

With certain types of item for which the level of the quietest passage was too low to operate the control circuit, the gain of the amplifier returned to its no-signal value so that the programme volume was reduced. Conversely, with a high level of background noise, the control circuit was operated during intervals as if for a quiet passage in the programme and the output level raised. Since the device is not capable of distinguishing between noise and quiet programme, the control R2 needs to be re-set according to the nature of the item if anomalous operation is to be avoided.

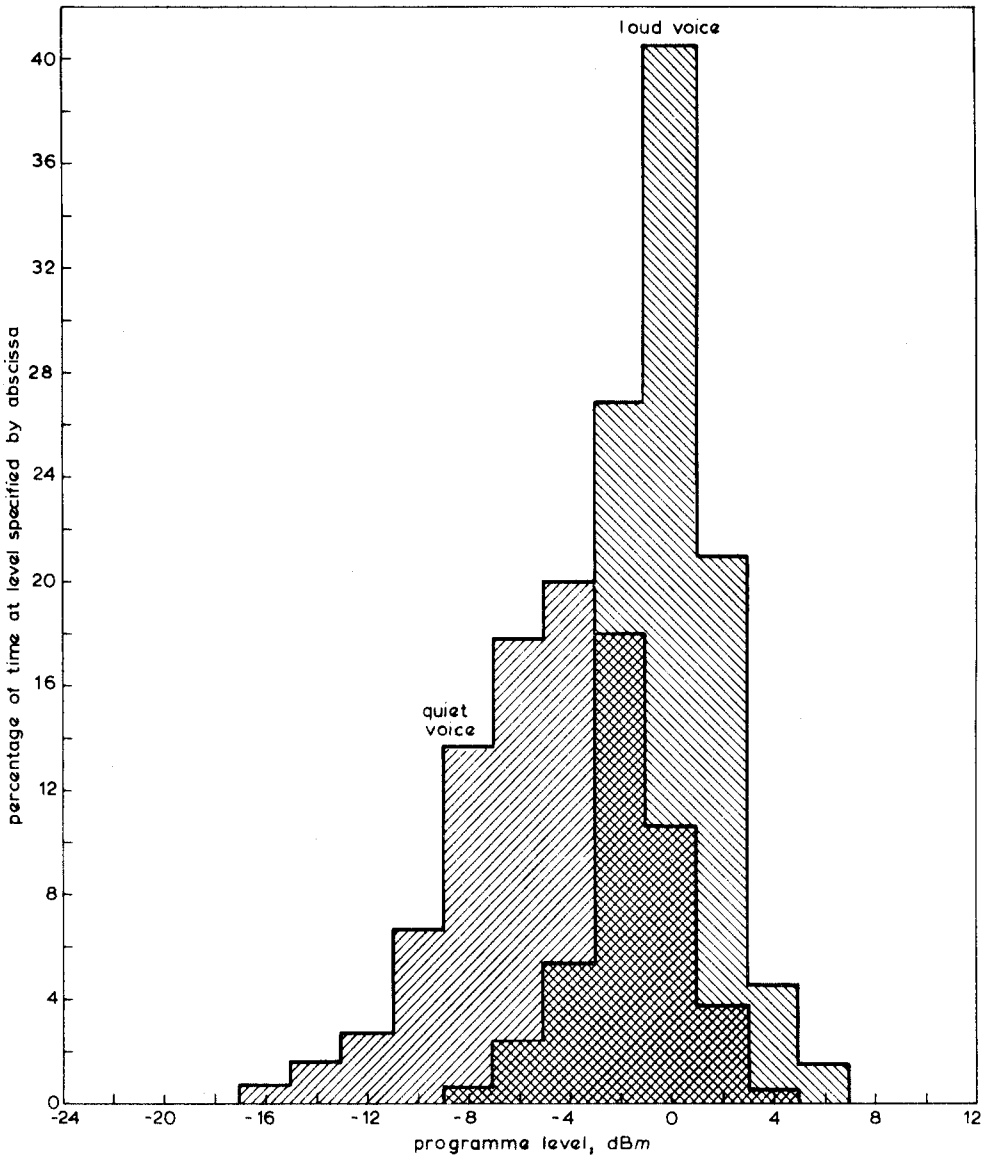


Fig. 9 - Level distribution of voices after passage through LIM/6 with 12 dB maximum gain reduction

Non-linear distortion due to dynamic overloading was clearly audible on all programme. In principle, it should be possible to reduce this distortion to negligible proportions by providing a greater safety factor against transient overloading of the amplifier; however, it is estimated, from experience with other automatic gain control devices, that an increase of at least 10 dB in the overload level would be necessary.

7. CONCLUSIONS

The "Audimax" gain control amplifier shows certain advantages over other automatic volume regulating devices. The reduction in dynamic range is slightly greater than that obtained with conventional quick-acting compressing devices. The long recovery time reduces "gain pumping"; at the same time, the gain is prevented from rising to its full value in the absence of programme, thus avoiding an undue increase in background noise. The latter feature, however, involves in effect an amplitude-sensitive gating circuit which, being unable to distinguish between low level programme and high level noise, needs to be adjusted according to the nature of the item; this requirement detracts from the usefulness of the device for unattended operation.

The rise in gain at the commencement of a very quiet passage is so slow that under adverse reception conditions, some of the programme might be lost to the listener; moreover, in some types of music, this slow rise could be aesthetically objectionable.

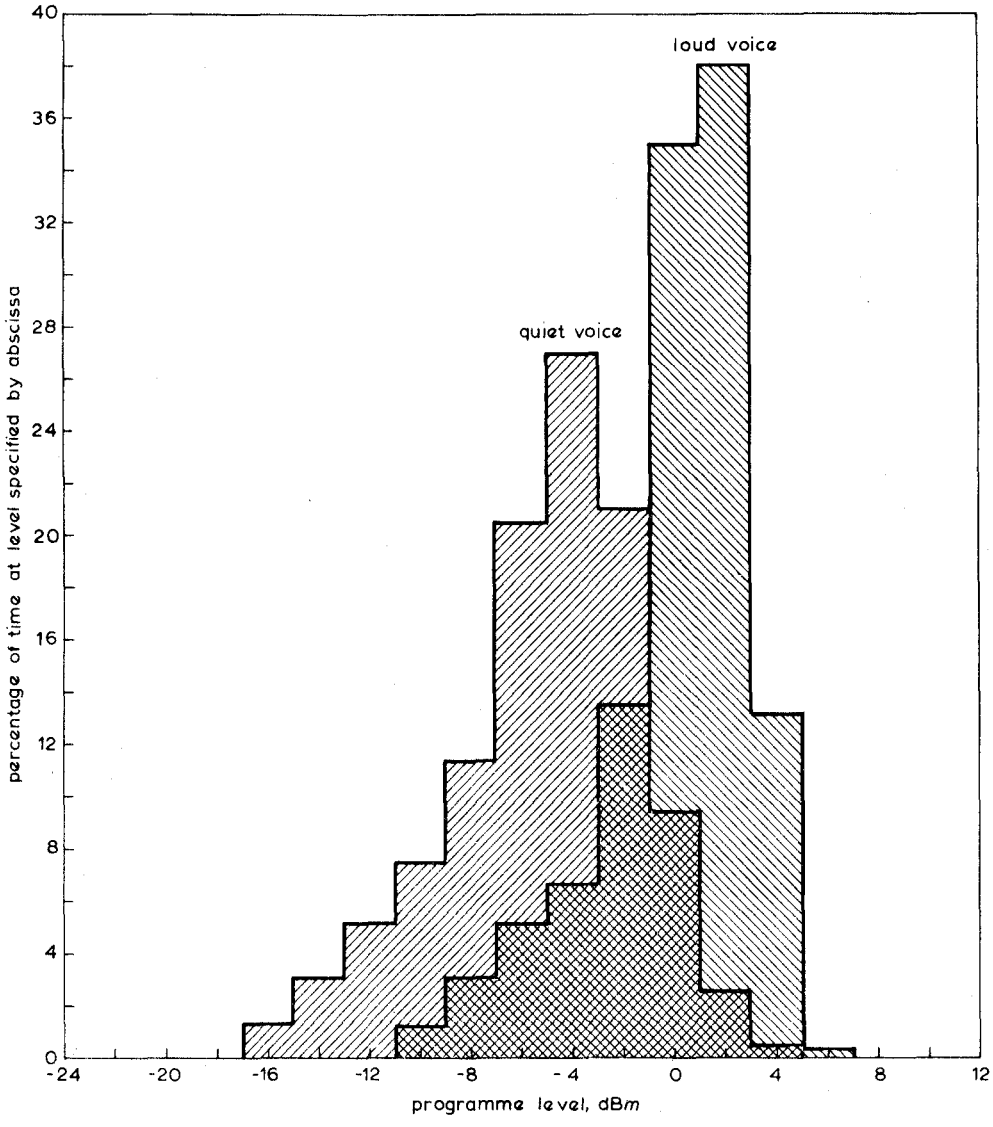


Fig. 10 - Level distribution of voices after passage through 2 : 1 compressor, with 12 dB maximum gain reduction

The amplifier produces appreciable distortion, but this defect is not inherent in the principle of operation and could possibly be overcome by some refinement in design.

The device is somewhat costly, the price to the BBC in 1965 being £229; it should be noted that this price is in addition to the cost of the associated limiter.

8. REFERENCE

1. New equipment for the statistical analysis of programme levels. BBC Research Department Report in preparation.

SMW

Printed by BBC Research Department, Kingswood Warren, Tadworth, Surrey