RESEARCH DEPARTMENT

AN INVESTIGATION OF SPEECH COMPRESSION SYSTEMS

(INTERIM REPORT)

Report No. L.024
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Fig. Nos. L.024.1,2

SUMMARY

Consideration has been given to several systems of speech compression including the Langevin amplifier used at certain BBC transmitters. It is shown that by slight changes in circuit values and the use of a limiter, the performance of the Langevin equipment can be considerably improved.

1. INTRODUCTION

Following a request from A.C.E. Research Department has investigated the potentialities of systems of speech compression designed to increase the intelligibility of signals received through jamming.

The first consideration was to determine whether the existing Langevin amplifiers employed for overseas transmissions are being used to the best advantage; the second, to investigate the possibility of improving the performance of these amplifiers by means ready to hand and the third to examine any alternative methods of speech compression. The first two subjects are dealt with in the present report.

When the investigation began, a system of speech compression employing carrier technique was under consideration. This system, suggested by a member of Research Department, need not be detailed here. It is, however, capable of compressing the signal level to a very high degree without appreciable time lag and without generating intermodulation distortion. A working

model of the carrier system was built up with equipment lent by the Ministry of Supply. Although not immediately applicable to operational use, it served as a useful standard of performance, especially as it allowed the effects of excessive compression to be studied.

The essentials of a speech compression system are:

(a) to provide means for eliminating from the signal low frequency components which, while adding to the peak power of the speech waveform, contribute little to intelligibility, and means for emphasizing the more important high frequency components.

(b) to provide means for compressing, within as small a compass as possible consistent with intelligibility, the varying amplitudes which represent the signal waveform. The method of compression is chosen with due regard to its effect on the characteristic emphasis in speech and also to the production of sum and difference distortion products in the speech frequency band.

(c) to provide means for eliminating any unwanted components, generated in process (b), which lie outside the speech-frequency band.

Requirement (a) is met by bass-cut and top-lift circuits, (b) by a form of diode "clipping" circuit and (c) by networks designed to remove high frequency components which would otherwise produce interference in adjacent channels.

A number of variants of (a), (b) and (c) is possible and each of these features was made the subject of experiment. For the purpose of the tests, separate equipment was built up comprising the best combination. This included a slightly more severe bass-cut than that already provided in the Langevin amplifier.

A considerable improvement in intelligibilty was obtained by the introduction of a limiter with a short recovery time immediately ahead of the diode circuit. Without this provision the degree of amplitude compression varies from syllable to

syllable, even with a carefully controlled speech input, the stronger syllables being excessively distorted while the weaker are still masked by the jamming. For the purpose of the tests, a LIM/2 was used with the time constant switch set at position 1; in this condition, the gain of the variable-mu stage can recover, after the cessation of a signal, at the rate of about 10 db in 0.2 second.

Finally, tests were carried out on the Langevin amplifier with such slight changes in the circuit constants as had been suggested by the tests and with the quick-acting limiter connected between the two sections into which the amplifier is divided. Although, for reasons already given, the limiter should in theory be connected as described, this arrangement may lead to operational difficulties. At the suggestion of Designs Department, therefore, a series of tests was later undertaken with the limiter connected in front of the Langevin amplifier. These tests are dealt with in an Appendix to this report.

2. METHOD OF TEST

A representative circuit was set up using a high quality miniature transmitter, fed from the compression system on test, and a commercial radio receiver (Murphy type A.170) loosely coupled to it on a frequency of 0.81 Mc/s. Jamming was represented by "noise" generated by a gas discharge tube,* suitably adjusted in frequency content, injected into the audio chain of the receiver. Short sentences taken at random from newspapers were read, and a crew of three or four listeners recorded the number "immediately appreciated".**

In assessing the merits of the various systems, the intelligibility of an uncompressed signal was determined for comparison. It was very difficult to get any consistent results owing to the large (although unintentional) variations

* Research Report M.011

** See W.H. Grinsted, Siemens Magazine, January 1937

in the speaking level. A limiter with a long recovery time was finally employed in all the tests to take care of this; the time constant switch was set to position 3, giving a gain recovery time of about 4 seconds for 10 db. Used in this way, the limiter did not compress the signal but served to take the place of a skilled operator controlling the programme manually over a range of some 4 db.

3. DISCUSSION OF RESULTS

In the attached figures, the sentence score, expressed as a percentage, is plotted against the noise/signal ratio. The latter has an arbitrary origin, the point at which the level of the noise is equal to the level of a sine wave which would cause 40% modulation of the transmitter, both quantities being measured at the output of the receiver by a valve voltmeter reading the mean value of the waveform.

The vertical scale in the figures is of a special type * used in statistical investigations. It is so chosen that the curves obtained from intelligibility and similar tests are approximately straight and can therefore be more readily compared.

In interpreting these diagrams, it should be borne in mind that a score of 50% corresponds to most wearisome and exhausting listening conditions. It is unlikely, therefore, that the part of the graph lying below the 50% line applies to the average listener. Again, the sentence score is not directly related to the intelligibility of connected discourse, for the loss of the critical sentence may render large sections of the remainder valueless.

For both these reasons, the upper half of the graphs is the more significant for the present purposes. To give a numerical basis for assessing the relative merits of the various systems, the interval between the graphs at the 75% intelligitility level

* Wightman Mountain Data Sheet No. 37S Permille (arithmetic probability)

has been taken. For example, if the interval between any two curves at the 75% intelligibility level is 2 db, the system represented by the right-hand curve will give as good a service as that represented by the left-hand curve in spite of a 2 db higher noise/signal ratio.

Fig. 1 shows the difference between uncompressed speech and speech which has been passed through a Langevin amplifier set for 9 db or 12 db clipping. The improvement obtained by the use of the Langevin amplifier will be seen to be between $3\frac{1}{2}$ db and 4 db. The higher degree of clipping gave an impression of increased intelligibility due to the greater average volume, but these tests show that this was spurious.

Fig. 2 shows the curve obtained with a Langevin amplifier set to "9 db clip" and modified by circuit adjustments and the addition of a limiter as described giving 10 db compression of the highest peaks of signal. The improvement as compared with uncompressed speech is between $5\frac{1}{2}$ db and 6 db. Tests on the carrier system referred to earlier showed that the performance cannot be improved indefinitely by increasing the degree of compression. It is doubted whether the results obtained with the combination of modified Langevin amplifier plus limiter with the degree of compression specified can be improved appreciably.

The scores shown in Figs. 1 and 2 were repeated fairly precisely on a number of separate occasions but only after the greatest care had been taken in setting up the transmission chain to ensure that the maximum modulation depth was the same in all cases. It will be seen from Figs. 1 and 2 that a small change in noise/signal ratio can produce a large change in the intelligibility score. For example, in the case illustrated by the right-hand curve of Fig. 2, an increase of only 1 db in noise/signal ratio, such as might result from an error in setting the maximum transmitter modulation, could reduce the intelligibility from 75% to 50%.

4. CONCLUSIONS

To obtain the highest possible intelligibility through jamming it is necessary:

(a) to apply a bass-cut and top-lift to the frequency characteristics of the system;

(b) following process (a), to compress the signal some 10 db with a quick-acting limiter;

(c) to apply the resulting signal to an amplitude limiter as typified by the "clipping" stage of the Langevin amplifier;

(d) to present the resulting signal to the transmitter so that the highest possible modulation depth is maintained at all times.

The Langevin amplifier as manufactured satisfies requirement (c) and partially satisfies requirement (a). By the use of this device, a given service can be maintained in spite of a noise level $3\frac{1}{2}$ - 4 db higher than that which could be tolerated if the speech were not compressed. The changes in circuit constants and the introduction of a quick-acting limiter as already described raise this figure to $5\frac{1}{2}$ - 6 db and it is considered unlikely that any great improvement could be achieved with the aid of any alternative system.

It must, however, be remembered that whatever system of compression may be used, its effectiveness in overcoming jamming is critically dependent on the depth of modulation at the transmitter. Thus, it is possible for a small operational error to nullify the effect of the various technical improvements made to the compressor. Instructions on the proper maintenance of modulation depth will need special investigation in service. Recommendations on the lining up of transmitters in conjunction with the special compression systems described in this report will be dealt with in a technical memorandum.

APPENDIX

1. At an early stage in the investigation, it became clear that a limiter should be used and that it should preferably be connected between the two sections of the Langevin amplifier. Designs Department was advised of this requirement and proceeded to consider its operational implications.

The output impedance of the first section of the Langevin amplifier and the input impedance of the second section are both 600 ohms and the signal levels at these points are suitable for the operation of a limiter. The introduction of a limiter might nevertheless lead to operational difficulties. In practice, provision has to be made for using the limiter (a) as a speech compressor in conjunction with the Langevin amplifier and (b) as a general-purpose compressor for programme material other than speech.

The first section of the Langevin amplifier incorporates bass-cut and top-lift circuits which could not be allowed to remain in circuit in condition (b); thus the change from (a) to (b) involves switching operations. These operations could be simplified if the limiter were placed ahead of the Langevin amplifier and it was suggested by Designs Department that the possibility of using this alternative arrangement should be investigated.

2. After a series of intelligibility tests on the lines described in the report, the conclusions reached were as follows: By placing the limiter ahead of the Langevin amplifier instead of between the two sections:

2.1 The performance of the system, in terms of the noise/signal ratio for a given intelligibility score is, roughly speaking, unchanged at the 75% intelligibility level but slightly inferior at higher levels.

2.2 The speech quality is inferior, the effects of room reverberation being more exaggerated.

2.3 The maximum useable degree of clipping remains at the "9 db clip" setting on the Langevin amplifier.

2.4 It should be borne in mind that when there is no bass-cut ahead of the limiter, the behaviour of the system is largely conditioned by the frequency spectrum of the speech signal presented to it. With the limiter placed in front of the Langevin amplifier, considerable variation in performance is, therefore, to be expected as between one voice and another. In the time available for the tests referred to in this appendix, it was not possible to investigate this effect fully.

3. From the above, the following conclusions may be drawn:

3.1 A limiter used in connection with a Langevin amplifier should preferably be connected between the two sections of the amplifier as described in the report.

3.2 Where this arrangement is not possible, the use of a limiter ahead of a Langevin amplifier will, however, give a worth-while improvement.

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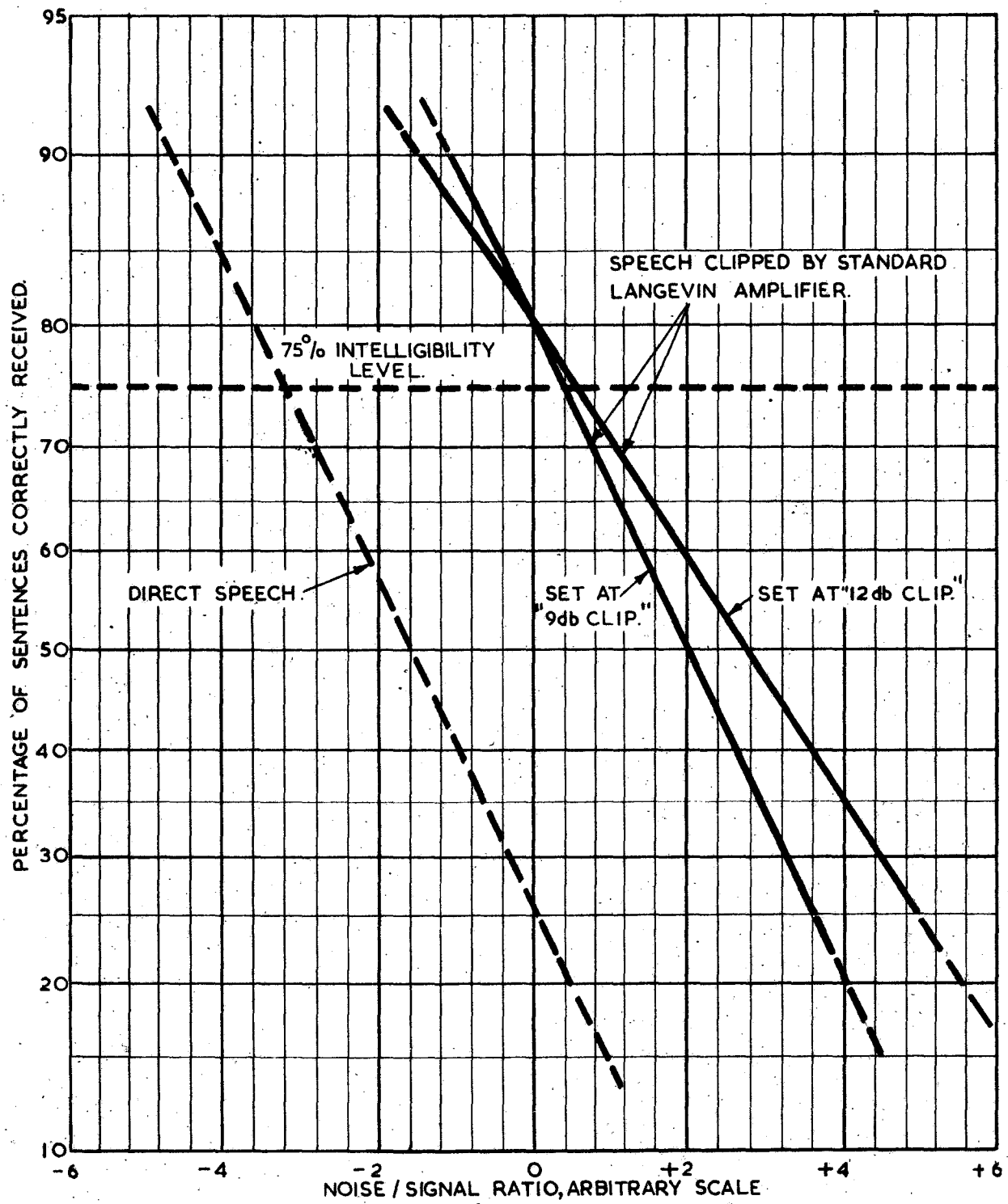

FIG. 1

EFFECT OF STANDARD LANGEVIN AMPLIFIER.

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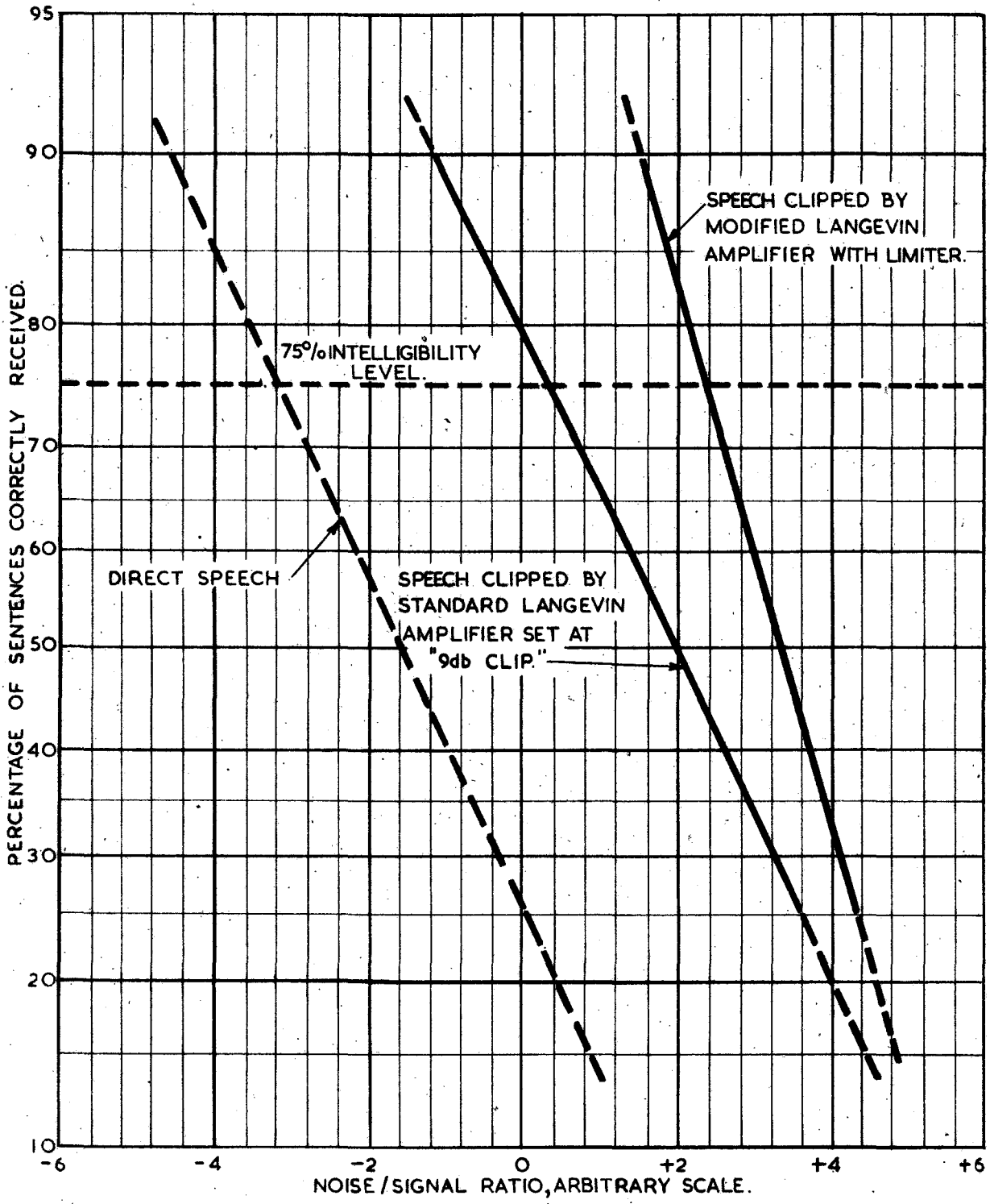

FIG. 2

EFFECT OF MODIFIED LANGEVIN AMPLIFIER WITH LIMITER CONNECTED BETWEEN "AMPLIFIER" & "CLIPPER" SECTIONS.