RESEARCH DEPARTMENT

THE RELATIVE MERITS OF THE V.U. METER AND PEAK PROGRAMME METER IN THE REGULATION OF A.F. SIGNALS IN BROADCASTING

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SUMMARY

The relative merits of the 'V.U. meter' and 'Peak Programme Meter' (P.P.M.) as volume-indicating devices have been hotly if inconclusively contested for many years; this article introduces some points which merit fuller discussion and is based on the experience gained by the BBC in the last decade.

The conclusion is confirmed that a quasi-peak reading instrument such as the P.P.M. is superior to a quasi-average reading instrument such as the V.U. meter because it gives an unambiguous indication of the instantaneous modulation depth of the transmitter. A comparison is also made between these volume indicators in regard to their use for the measurement of transmission loss in lines, and for assessing 'loudness'.

1. INTRODUCTION

Efficient transmission of programme signals from the broadcasting studio to the listener demands the highest possible average value of modulation depth at the transmitter. It follows that any measuring instrument involved in the general observation and regulation of the programme signal must have properties such that the meter readings give a clear measure of the transmitter modulation depth.

Quasi-peak reading instruments used by a number of European broadcasting organisations, including the BBC, give readings which represent, with reasonable accuracy, the crest value of the signal envelope. The American V.U. meter can be employed for the same purpose, but as it is designed to read the quasi-average of the rectified envelope rather than of the crest value, its readings have to be interpreted with caution, and it cannot be relied upon to give consistent results.

This report provides evidence in support of these statements and the opportunity is taken to clear up some misunderstandings about the relative merits of the V.U. meter or the P.P.M. for loudness comparisons and for the estimation of transmission-loss in long programme transmission circuits.

2. THE MAINTENANCE OF HIGH AVERAGE MODULATION DEPTH

The maintenance of the highest average modulation depth consistent with artistically acceptable presentation of the programme must necessarily be the objective of every broadcasting organisation. The volume of programme signal must lie between an upper limit set by the transmitter and a lower limit imposed by noise in the transmission system. As the signal from the studio microphones varies over a very wide range (not only because of the continually changing content but also because the sounds may originate at various distances from the microphones) it is essential to restrict the dynamic range of the programme signal. If intelligibility is the only criterion, it is justifiable to restrict variations in the signal very severely - as for example in short wave transmissions subjected to 'jamming' - and in such circumstances a very consistent and high modulation depth can be ensured by 'compressors' or similar electronic aids. In good broadcasting practice, however, a reasonable degree of light and shade in a signal is necessary; to achieve this, and at the same time to keep the dynamic range of the programme within acceptable bounds, calls for human intervention. The operator responsible for regulating the programme is provided with some kind of volume indicator to assist him in his task. The volume indicator is a visual aid, and to be of real use it must give clear warning when the upper limit of signal crest voltage which corresponds to the maximum permissible modulation depth at the radio transmitter is approached.

In the United States and in a few European countries, the volume indicator adopted gives a reading which is proportional to the mean rectified value of a steady signal. In the case of a signal varying with time, the value indicated is the short-term quasi-average of the rectified envelope. In the BBC and in Germany, as well as in other European countries, the volume indicators give a reading corresponding to the quasi-peak or crest value of the signal.

The proponents of the American V.U. meter tend, however, to overlook the primary purpose mentioned above: a volume indicator must give the operator continuous and exact information about the modulation depth at the transmitter. As will be shown later, the V.U. meter is not designed for this specific purpose, and it cannot provide the information required. The P.P.M., on the other hand, is designed to give with reasonable precision a measure of the peak voltage represented by the successive bursts of programme signal, and it successfully does so.

It is often argued that broadcast programmes are kept quite successfully within the requisite dynamic range by operators provided with V.U. meters. The truth of this is a tribute, not to the meter's performance, but to the skill and experience of the operators.

3. THE REGULATION OF THE MAXIMA AND MINIMA OF THE PROGRAMME SIGNAL RANGE

Whatever the programme material involved, the operator has to regulate the varying microphone signal so that the volume of the programme signal falls between predetermined minimum and maximum limits. The upper limit is far more clearly defined than the lower, for any peak which exceeds the limit will not only become audible as a distorted sound but will also upset the performance of an amplitude-modulated transmitter. In the case of an f.m. transmission the distortion is likely

to originate, not in the transmitter, but in the discriminator of the listener's receiver. Thus overmodulation leads to distortion of one kind or another and has to be avoided. Moreover, in many cases the circuit carrying the programme from studio to transmitter is provided in a multi-channel carrier system, and excessive peaks are particularly liable to upset the behaviour of such a system, affecting not only the quality of the programme in question, but also the performance of a large number of telephone channels. The Telecommunications Administrations are understandably strict in insisting that the maximum permissible sending amplitude shall not be exceeded, even for very short periods that produce no audible impairment of the broadcast programme itself.

To make quite sure that high programme signal voltages do not reach the modulating stages of transmitters accidentally, it is common practice to provide automatic gain-control devices. The limiters in use by the BBC have an operating time constant of 2 to 3 milliseconds and, beyond causing transitory restriction of the input signal voltage, do not produce any distortion audible to the listener. An alternative is to use 'compressors'; these - unlike the limiter - operate in terms of the running-average of the voltages applied to them in excess of a stipulated maximum, and a certain amount of distortion is inevitable so long as they are in operation. Limiters are not, however, normally used at the sending end of line-transmission circuits* and thus it is most important that the programme volume sent to line should be effectively controlled, and excessive peaks eliminated.

4. OBSERVATIONS ON THE PERFORMANCE OF THE V.U. METER AS A PEAK-INDICATING INSTRUMENT

As already stated, the operator requires guidance in respect of the crest-value of the programme signals which he controls. It is therefore justifiable to include peak-voltage measurement among the tests applied to the V.U. meter. Accordingly, test material was prepared by recording two speech and two musical programme items, the signal being automatically regulated to a virtually constant peak voltage by means of a limiter of BBC design. Each recording was played back to a V.U. meter, a BBC peak programme meter and an oscilloscope simultaneously. The P.P.M. and the oscilloscope agreed in showing that in all four recordings the crests of successive signal bursts were substantially constant; the V.U. meter disagreed.

Because of the large time constant of the pointer system of the V.U. meter a steady voltage, corresponding to the maximum shown by the oscilloscope, produced, with one voice, an average reading of 5 dB below this maximum and, with another, 10 dB. A light orchestral recording indicated on the average 10 dB low and jazz music 5 dB low. In all four cases the successive bursts of programme signal produced V.U. meter readings which fluctuated about these averages by an amount which varied with the programme material by $\pm$ 4 dB as a maximum and $\pm$ 2 dB as a minimum.

A further step in these investigations was made in which the signals were no longer artificially limited to a fixed maximum voltage. Again the readings of the V.U. meter were compared with those of the P.P.M.; the same general order of differences was still in evidence.

* Note, however, that the Sound Sub-Group of E.B.U. Working Party L has recently been given the task of establishing a specification for a limiter that could be used for that purpose.

Regular users of the V.U. meter believe that it 'tends to read low' by some 6 dB and that this tendency can be corrected by increasing the gain in the V.U. meter preamplifier by a corresponding amount. This statement is not borne out by tests. Experience in the laboratory has shown that there is no fixed correction which is of universal application. Indeed, if an operator were to rely upon a fixed correction to bring the V.U. meter readings into line with the crest voltage of the programme signal, he would find himself grossly misled.

One must assume, therefore, that when successful regulation of a programme has been achieved by an operator who relies upon a V.U. meter, it has been done largely by ignoring the detailed meter readings and by relying instead on experience or upon alternative aids. In this regard it is to be noted that the operators' difficulties are already recognised by the Columbia Broadcasting System in the United States which has published[1] a description of an auxiliary device to over-ride and compensate for the inadequate information given by the V.U. meter readings. The device in question gives warning of - and is operated by - the crest of the programme signal voltage. As it over-rides the V.U. meter readings, it is difficult to understand why a peak reading meter is not substituted for the combination of V.U. meter and auxiliary device.

5. THE USE OF PROGRAMME METERS FOR TRANSMISSION MEASUREMENT

It is essential that the transmission equivalent of the line connecting studio and transmitter be held constant once the modulation depth at the transmitter has been fixed in terms of the programme meter-reading in the studio. As the programme cannot be interrupted the transmission loss is conveniently measured by means of two programme meters, one at each end of the circuit, and the loss between the two measuring points is derived from the difference between the meter readings. The apparently simple operation of taking the difference of the readings is complicated by two factors; one arising from the electrical properties of the transmission line, and the other from the operators' difficulties in making judgments. The operators' difficulties are too often overlooked.

Let us consider the operator first. A very short trial will prove that it is impossible for an operator who is telephoning his meter readings to his colleague at the distant end of the line to observe every single meter deflection. It must be borne in mind that with a P.P.M. the peak-rate always exceeds 25 per minute and may even rise to 48 peaks per minute, while with the V.U. meter the rates are even higher. (With certain types of programme, e.g. didactic speech, the peaks come in groups, and the operators may agree upon the *maxima maximorum* within the group.) If, however, the operator's estimate is based upon one signal-burst among many it may not be representative, and he will wait and try again. Thus, there is considerable delay in deriving the difference in the readings, and it is often difficult to assess a consistent difference between near- and far-end P.P.M. readings.

If the transmission line is long there is dispersion of the higher frequency signal components, due to phase distortion, which will tend to reduce the steepness of the wave-front. This results in a lower reading of the distant P.P.M. It may well happen, for example, that the maximum peak produced within a sentence is also one which contains a large proportion of sibilant sound, and in this case undue

attenuation will appear to exist. If, however, low-frequency vowel-sounds are used for assessment, there will be no significant dispersion to confuse the situation, and the transmission equivalent will appear normal.

In the BBC, when the P.P.M. is used, it is possible to make a simple circuit modification which substantially removes both the human and the electrical sources of error; the meter can be switched, when required, to read a 1·0 second time-average of the normal readings. The reading is thus converted into a series of relatively slow undulations, the crests of which are well defined, and the effective transmission equivalent can be estimated from them within 5 to 10 seconds.

This procedure has been in regular use over the last ten years or more for monitoring the BBC land-line network during programme hours.

6. V.U. METERS AND PEAK-READING INSTRUMENTS USED AS LOUDNESS METERS

It can be stated at once that controlled experiments refute statements that, of the two meters, the V.U. meter provides a better objective measure of the relative loudness of two sound-signals. Indeed, such claims are unsupported by the designers of the V.U. meter, who have demonstrated (Table IV of Reference 2) that neither the V.U. meter nor a quasi-peak reading instrument can even indicate reliably the loudness of male speech in relation to female speech, or to a variety of musical items - the meters read 0 to 3 dB low in one case and 2 to 2·5 dB high in the other.

It is also known that peak-measuring indicators are useless as loudness meters. It is, however, worth considering what the outcome might be if a true loudness-measuring instrument were available. In such circumstances an operator would be somewhat embarrassed. He would be forced to regard the P.P.M. as the master control of upper limits of volume, while relying upon the loudness meter for the monitoring of intermediate levels.

There is already a conflict between the operator's built-in loudness meter, i.e., his aural judgment, on the one hand, and his visual impression of signal maxima on the other. It is in fact an important feature of the operator's duties to resolve it. He does it by reconciling aural and visual impressions. An operator who is continually forced to decide between two sets of rapidly fluctuating meter readings observed simultaneously would soon be exhausted, and the final outcome would probably be chaos. The addition of a loudness meter to a P.P.M. would, it is considered, be more of an embarrassment than an aid to good control.

7. CONCLUSIONS

To achieve the maximum broadcast programme volume consistent with the avoidance of overmodulation of the transmitter or interference with other channels of a carrier system, the circuit gain has to be regulated in accordance with the crest value of the signal from the microphone.

The differences in performance between the V.U. meter and the peak reading type of meter as an indicator of transmitter modulation have been quantitatively

illustrated. The factor relating the V.U. meter reading to the crest value of the waveform varies considerably between different types of programme item; as a result a consistent level of modulation can be obtained only by utilising additional information supplied by the accumulated experience of the operator or even by a supplementary instrument.

Difficulties formerly experienced in checking the transmission equivalent of a line carrying programme can be overcome by automatic long-term averaging of the meter readings. The P.P.M. lends itself readily to this procedure, which has proved itself over a long period of service.

Neither the V.U. meter nor the peak reading instrument is a reliable guide to the relative loudness of different types of sound. Since, however, the operator is in any case obliged to use his ears, it is unnecessary and even undesirable to employ a supplementary visual indicator for loudness.

8. REFERENCES

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