On Measuring Frequency Variations

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Abstract

The major proposals for the measurement of frequency variations are discussed. It is shown that the measurement of peak value offers considerable practical advantages over an rms measurement. A curve is shown of the subjective evaluation of flutter as a function of flutter frequency; this curve is a compromise between several proposals. These proposals have now been adopted nationally in Germany and the U.S.A., internationally by the International Radio Consultative Committee (CCIR), and are under consideration by the International Electrotechnical Commission (IEC).

I. Introduction

When moving the medium in a sound recorder, unavoidable frequency variations ("flutter") are created. There is an increasing need for a measurement of these frequency variations that will reasonably well predict the subjective effect of the frequency variations; in other words, we need measured values that predict the audible quality.

The CCIR Recommendation 210 of 1956 specified the test frequency to be used, and the variation-frequency range; but various models of measuring equipment differed from each other in two important points: the kind of rectification and the weighting curve. Similarly, the now obsolete ANSI and IEEE standard [1] did not specify the meter dynamics and did not require a weighting curve.

II. Rectification

There are a number of studies on the effect of the kind of rectification; these contain some very careful measurements. Most of the tests were done with sine waves, but after many experimental problems were solved, music and speech were also used. The latter deserve special attention, since they correspond to the practical situation. While some authors prefer rms measurements [1], [2], [4], [6], others recommend peak readings [3], [5]. This is so much the more remarkable as, in order to obtain clear audible effects, some of these tests were made with frequency variations (flutter) having a high peak-to-rms ratio.

One would therefore suppose that the correlation between the subjective flutter and the reading on present-day instruments would be very poor. The fact is, however, that the difference between the reading of an rms meter and that of a peak meter is much smaller for the frequency variations found in practice than for the artificially created frequency variations mentioned above; therefore, the practical importance of the question of peak versus rms measurements may be less than these studies would indicate. In other words, one could measure either rms or peak values. In order to obtain comparative readings, however, one must for the sake of uniformity select *one* of the two.

There is a practical reason, however, why the measurement of the peak value seems to be better. When the entire frequency range from 0 to 200 Hz is measured (as specified in the CCIR Recommendation 210, 1956) a problem occurs when an rms measurement is attempted at these very low frequencies. While known techniques permit accurate rms readings at mid and high frequencies, at low frequencies the pointer moves up and down the scale, giving an undefined reading, since the meter does not average over a long enough time to determine the rms value over several periods. When the frequency becomes low enough, the pointer will follow the instantaneous value of the wave, that is, read the peak value at the maxima. Finally, at zero frequency (dc) the rms and peak values are identical.

Sometimes these difficulties are avoided by reading the rms value at higher frequencies and the peak value at lower frequencies. Where these ways of reading overlap, two different values will of course be obtained for the same condition, the ratio of the two depending on the waveshape of the frequency variations. Although this may be satisfactory for purely comparative measurements, it leads to prohibitive difficulties in a meter where a prediction of the subjective audibility of variations containing components of different frequency are required. This difficulty is avoided if peak readings are used entirely.

Because of this practical advantage, the definitions and measurements to predict subjective flutter should be in terms of the peak values.

III. Response of the Weighting Network

The necessary frequency weighting has also been determined both for sine waves and for speech and music programs. As before, the music and speech tests are of the greatest significance.

Even though the results of the different tests differ considerably from each other, there is still a common tendency that cannot be ignored. The various curves from the literature are shown in Fig. 1. The numbers on the curves correspond to the reference numbers. Curves 1 to 3 were obtained using sine waves and curves 4 and 5 using music and speech. The heavy curves (1 through 4*a*) show an interesting coincidence in the range of greatest interest. In curve 5 the maximum is clearly moved toward higher frequencies. Be-

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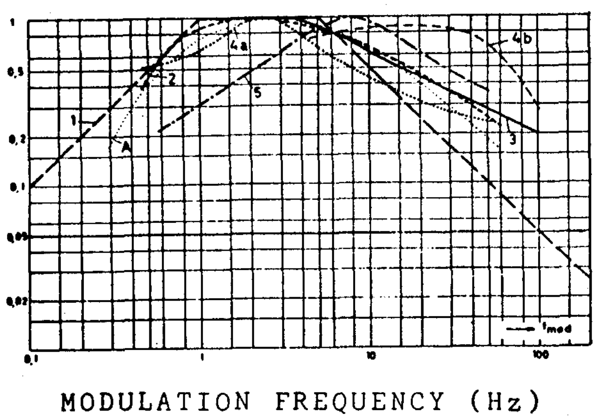

Fig. 1. Weighting factor versus modulation frequency. The numbers on the curves refer to the corresponding works in the References.

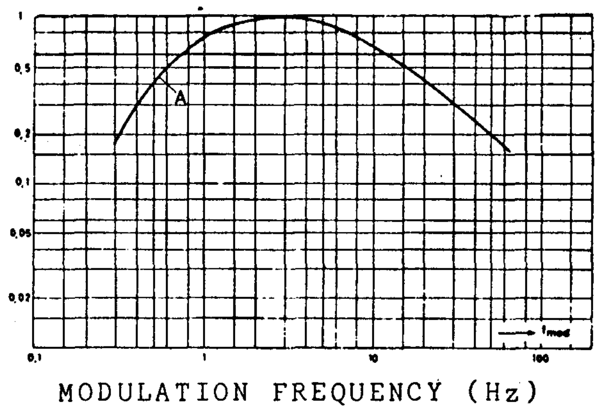

Fig. 2. Compromise proposal for the weighting factor versus modulation frequency, on the basis of the curves specified in Fig. 1.

cause this data is from very careful and extensive tests using music and speech, it cannot be disregarded, especially since curve 4*a* (also for music and speech) shows a slight tendency in this direction. The curve 4*b* (obtained using the same program) is less important here since it is valid only for transmission by lower quality systems. It is, nevertheless, interesting that here again a greater weighting is used for the higher frequencies. Judging from the existing material, one can conclude that with normal programs (i.e., with sounds of relatively short duration) lower modulation frequencies are less apparent than with continuous tones. The curve shown in Fig. 2 is a compromise between the different data in the literature (it is shown in light weight in Fig. 1 as "*A*").

Since it can hardly be expected that a final solution for the optimum curve shape can be obtained for the average of all of the program material of interest, the recommendation for a single measuring method to predict subjective flutter and wow uses the curve of Fig. 2 for the frequency weighting. This curve is easy to realize in practice.

IV. Standardization

The weighted peak flutter measurement method originally proposed herein has been incorporated in the German Standard DIN 45 507, first published in 1962, with minor revisions in 1966. The method is also incorporated in the CCIR Recommendation 409-1, 1966 and 409-2, 1970.

The weighting curve given here is incorporated into the flutter measurement method given by NAB in their 1965 tape recording (open-reel) standard, although the peak-measurement method was not included at that time due to lack of experience at that time with the peak-measuring method.

The IEEE has adopted this weighted peak flutter measurement method (IEEE Standard 193-1971); ANSI is considering adoption (ANSI S4.3-draft); and IEC is considering adopting this method (Doc. 60A(CO)12, Jan. 1971).

References

[1] CCIR Doc. 187 (VIIth Plenary Ass. London, 1953), submission by U.S.A. (Substantially identical to IEEE Standard 193-1953; also ANSI Standard Z57.1-1954, *American Standard Method for Determining Flutter Content of Sound Recorders and Reproducers.*)

[2] CCIR Doc. 364 (VIIIth Plenary Ass. Warsaw, 1956), submission by Japan, *Measurement of "Wow" and "Flutter."*

[3] CCIR Doc. 65 (VIIIth Plenary Ass. Warsaw, 1956, submission by Federal German Republic, *Investigation of Methods for Measuring "Wow" and "Flutter."* This report is essentially an English-language summary of the following German papers:
   a) E. Zwicker, "The limits of audibility of AM and FM of a tone," *Acustica*, vol. 2, Suppl. 3, pp. 125–133, AB 125, 1952.
   b) E. Zwicker and W. Kaiser, "The threshold of modulation within the auditory area," *Acustica*, vol. 2, Suppl. 4, pp. 239–246, AB 239, 1952.
   c) E. Zwicker, "On the audibility of non-sinusoidal pitch variations," *Funk Ton*, vol. 7, pp. 342–346, 1953.

[4] F. Comerci and E. Oliveros, "An audio flutter weighting network," *J. Soc. Motion Pict. Telev. Eng.*, vol. 65, pp. 419–425, 1956.

[5] A. Stott and P. E. Axon, "The subjective discrimination of pitch and amplitude fluctuations in recording systems," *Proc. Inst. Elec. Eng.*, vol. 102, pp. 643–656, Sept. 1955.

[6] CCIR Doc. 192 (VIIth Plenary Ass. London, 1953), submission by United Kingdom. (Identical to *Memorandum on the Measurement of Frequency Variation in Sound Recording and Reproducing*, British Standards Institution B.S. 1988:1953.)