On the Measurement and Evaluation of Disturbing Noise

By Ernst Belger

After a lecture in the colloquium of the NWDR Hamburg 20. January 1953

Über die Messung und Bewertung von Störgeräuschen
von Ernst Belger (Hamburg)
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Thanks to an anonymous translator, here is an English version with the diagrams in the original article. I have fine-tuned some expressions, attempted to translate captions for fig. 2, 3 and 9 and added my own translation notes in *[italics]*. A second translator has helped me further improve the text, up to page 5 so far. Hopefully I will be able to improve the text further in the future.

The full title of the journal is "Technische Hausmitteilungen des Nordwestdeutschen Rundfunks" which I think translates as "Internal Technical Memorandum of the North-Western German Broadcasting Service".

This English version is part of a research project http://realfield.com/anm/history/

> **The History of Low-Level Audio Background Noise Measurement**
>
> Especially techniques of assigning a single value to low-level background noise of various types, according to the degree to which humans find it annoying, disturbing or interfering (in German: Störgeräusche), with particular reference to the relative merits of RMS detection (dBA) and quasi-peak detection (CCIR 468 and related technical standards).

which includes graphic and OCRed scans of the original article in German.

Robin Whittle – rw@firstpr.com.au – Melbourne, Australia, 2nd July 2013.

Summary [Original English version]

After briefly discussing the problem, previous literature is quoted and an attempt is made to deduce from this the required characteristics for a psophometer having subjectively correct indications for audio frequency transmission chains.

It is shown to what extent the "Siemens & Halske" type J-77 psophometer meets these requirements, and a description is given of a series of tests into which the readings of the type J-77 psophometer were compared with the judgment of a fairly large number of observers.

In conclusion a report is given on some experiments undertaken with the object of establishing a psophometric weighting curve adapted as much as possible to subjective sensitivity as well as the signal to noise ratio required for high quality broadcast transmissions.

Summary

After a short discussion of the problem, a literature summary is made and from it is derived the necessary characteristics of subjectively correctly indicating noise measuring meter for audio transmission chains. It is shown, to what extent the noise amplitude meter model J-77 (Siemens & Halske) meets these requirements and a test series described, with which the indication of the J-77 with the evaluation by a large number of persons is compared. In the end the author's own investigations are reported, which were accomplished with the goal of determining subjective feeling as well as possibly adopting a quality evaluation curve and the necessary noise margin for high-quality broadcasting.

Problem definition

One of the most important parameters for the evaluation of the quality of an audio frequency transmission chain and/or its individual components is noise amplitude besides frequency response and nonlinear distortion. Thus it is not amazing that one went for a long time to the building of suitable instruments for the measurement of this noise voltage, although our knowledge is still quite incomplete about how annoying a noise is, regarding its frequency composition or its content of impulses. Beyond that, the opinions of individual authors in the literature often contradict each other. Just as disputed then are also the opinions with regard to the value of the measuring instruments, which were developed from these insufficient documents.

It's self-evident that the broadcast organizations, which are concerned in particular degree with high-quality transmission of sound events must have an interest in the creation of suitable methods and devices for the measurement of interference noise. The investigations, which were undertaken for clarifying these questions in the central technology group, were directed therefore from the beginning toward the practical; they aimed to separate from the controversy of the opinions so much that is surely known sufficient to build or evaluate measuring instruments. Particular attention was paid of course to the interferences and/or disturbance created to audio transmissions, such as noise, mains hum, switching transient noise, switching clicks and cross talk. In the following there shall be talk about these noises and their measurements in the first place.

The requirements imposed on an interference measuring instrument, are quickly formulated: It should gauge the degree of the annoyance, which the listener perceives, into an objective indication, into numerical values.

Who however is that, “listener?” Since the threshold sensitivity varies from person to person, we can proceed only with an average value. Well, is one to average over all listeners or better exclude people with obvious hearing errors? Then one might exclude all persons being less sensitive to higher frequencies due to their age. Hearing loss in treble begins however at teh age of approximately 30 years! Furthermore the interfering effect, substantially on the mental attitude, depends strongly on whether one hears a transmission only casually or with focused interest. This raises the question: which kind of program is to be regarded as standard? Finally, on the same level are the questions of whether and how one is to consider the room sound level and how the transmission equipment should be constituted, which one puts at the basis: As it today actually on the average is or like that, as it should actually be?

Facing such a flood of parameters, we can only help ourselves by specifying a set of them, on the basis of criteria which appear reasonable for the special purpose. However perhaps thus one does without general validity of the results or usefulness of the devices. For a broadcasting corporation, which attaches importance to the high quality of its transmissions, it is critical to select conditions as carefully as possible, thus high-quality material, accurate reproduction and young test subjects are used.

The next task would be to ascertain what the ear perceives under the determined conditions with the multiplicity of the arising interferences and then to build equipment, which resembles the ear therein if possible.

Literature

From the literature, little is to be learned about this question. There is a set of investigations about the volume of noises, but first of all volume and interfering effect are, as we will see in further detail, not at all always the same, and on the other hand such substantial contradictions exist between the individual researchers in the field we have difficulty drawing only reliable conclusions.

The volume of pure tones (sinewaves) sometimes – and such also appear sometimes as noise – is examined very thoroughly by ***Fletcher and Munson [1]*** and their predecessors. The investigations on the volume of the actual noises are much more incomplete. The following compilation is to give an idea of the most important publications, however only to the extent that the results can directly serve our purpose.

The classical work in this area is probably by ***Steudel [2]*** from the year 1933. Steudel examines clicks and click sequences. [Translators’ notes: “knack” is translated “click” but describes many other impulsive noises of expanded duration with additional lower frequency content.] He compares the volume of clicks of a certain form with pure tones and finds that the audibility of both depends equally on the amplitude. In this way is defined a scale of “normal clicks", which he uses for his measurements, since clicks are to be compared among themselves concerning their volume more easily than a click with a steady tone. For a click, as developed when discharging a condenser, he finds that the perceived volume increases as the discharge time constant increases up to 1 ms and remains constant then. He makes the transition to steady tone by measurements of ramped oscillations of 1000 cycles per second. A volume rise of approximately 10 phons results, if the duration increases from

1 ms to 100 ms. At still longer duration then the volume is equal to that of the steady tone. Likewise he finds a rise of 10 phons with periodic clicks, if he increases the recurrence rate from 1 to 50 clicks per second. A further increase of the repetition rate results in no more increase of the volume. Also interesting is an experiment with which he sends a very high crest-factor noise through a phase-shifting circuit, and a decrease of the volume around 7 dB is determined. The ear is proved with this experiment to be dependent on the phasing.

From these results Steudel develops a criterion for the volume of clicks. Thus one must integrate the pressure in the transient of the pressure change over a time of 0.3 ms. The resulting area will be proportional to the subjectively felt volume. With periodic noises the integration must be limited to one period. A special weighting of the individual frequencies – for instance according to ear sensitivity – is not required.

This form of the weighting is surprising at first sight. Steudel can compute thereby the volume of clicks and click sequences with good approximation, if he adds still the dependence of the volume of periodic clicks on the recurrence rate. Good approximation means here that the error remains below 4 to 5 phons. It is remarkable that also the volume can be quite well determined by pure tones of different frequency according to this rule, if one refrains from the highest frequencies.

As a particularly amazing fact it results from this formula that for instance a pure tone of 1000 cycles per second is not louder than the buzz [Schnarrton], which one receives, if only each twentieth half-cycle were present. This was also examined and confirmed by Steudel experimentally. This result seriously challenges the use of rms instruments for volume noise stress measurement.

Steudel undertook to develop a meter relating noises to amplitude. Since equipment, which makes the prescribed integration exactly, at a [desired] justifiable technical expenditure is not manufacturable, he proceeds thereby however from completely different principles.

The Steudel phonometer *[Lautstärkemesser]* consists of a weighting [ear] filter with following vacuum tube electric rectifier. The settling (rising) time constant lies thereby under 1 ms, the falling time constant with 50 ms.

Since Steudel's weighting filter leads with short impulses due to the phase shift to around 5 to 10 phons too low an indication, while it leaves a steady tone unattenuated through, steady tones are too highly valued. Steudel eliminates these, by making a half-wave rectification between filters and audion (rectifier + amplifier tube) so the peak voltage for sine waves is halved. [The original text reads "Zweiweggleichrichtung" 2-way-rectification, but only half-wave rectification meets the requirements described in the context.]

He obtains those with this equipment with practically occurring noises of results, from the means from approximately 9 persons only over about 2 to 3 dB deviation. The maximum deviation is 5 dB, which one can call quite good. It is interesting that Steudel could state that many test subjects could not differentiate cleanly between volume and annoyance degree.

Bürck, Kotowski and Lichte [3] 1935 accomplished similar investigations, whereby however the emphasis of their work is with unwanted clicks, like appearing unwantedly during companding. As far as comparable measurements are present, a satisfying equivalence with Steudel's exists. It is however remarkable that the authors believe that for regulation a measurement of the energy behind a weighting filter [Ohrfilter] meets the volume. The ear is after Bürck, Kotowski and Lichte, "a RMS-meter with 50 ms inertia [integration time] (like a hot-wire movement instrument)".

This principle is applied computationally to the clicks examined by Steudel and those so-received compared with the results of measurement. The agreement is however not absolutely convincing: Although the curves correlate well, there are still possible differences up to 10 dB, whereas still some assumptions are to be made about Steudel's test equipment.

Something similar applies in the 1936 work also from ***Bürck, Kotowski and Lichte [4]*** that concerns itself mostly with click sequences. One cannot always avoid the impression that facts were constrained for the sake of a principle –however a principle captivating in its simplicity, all of our concerns would be relieved if it were truly applicable.

An extensive work still lies from ***Garner [5] (1948)*** forwards, which examined the volume of consequences of short tone bursts. From the numerous results of measurement it is interesting here above all that perhaps interrupted pure tones can have the same or even a somewhat higher perceived volume than steady tones of same amplitude, although the latter possess more energy. This speaks clearly against a simple and effective evaluation. In this connection Garner and others come to similar results as Steudel found with the comparison of the pure tone with the buzz tone from each twentieth half-cycle. Finally still Steudel's realization is confirmed that with click sequences the volume rises around approximately 10 phons, if the recurrence rate is increased from 1 cycles per second to 50 cycles per second.

All aforementioned work refers, as already mentioned, to the volume and not to the disturbing effect. A noise will be all the more annoying in the general also, the louder it is. On the other hand however everyone knows from experience the fact that with very high frequencies the annoyance is far stronger than corresponds to the volume. One thinks only of the extraordinarily unpleasant tones, which one can produce, if one scratches for instance with a knife on a plate.

Furthermore it is to be considered that the level of the noises examined here throughout have a much higher level, than it is with interferences on broadcasting channels.

Consequences for the characteristics of measuring instruments.

We try to derive nevertheless once from evenly implementing the basis of how an interference voltage measuring instrument must be constituted:

First of all we will use a weighting filter, in order to correspond to ear sensitivity to individual frequencies. Then we saw that an effective evaluation leads impulses to show an unacceptably low indicated value, in relation to steady tones. We will thus select peak detection, and for symmetry reasons choose a full wave detector. The filter becomes the evaluation of the frequency sensitivity, to which electric rectifiers leave the evaluation of the result. Thus we made a division, which is actually completely inappropriate. The use of a weighting filter means the following: We divide the noise after Fourier into its individual components, evaluate the parts according to their frequency and build them up then again, in order to measure it. That would be however permitted only if the ear an corresponded to an effective rate indicating instrument, and only registered noises, without consideration for their temporal distribution and without consideration for the phase situation. Peak measuring equipment generally considers, as also the ear does, the phase position, but it is generally not used.

Fortunately however the errors resulting are not very large, and they are partially eliminated by a suitable dimensioning of detection.

During peak detection altogether four parameters are at our disposal: Two electrical, i.e. the charging and the discharging time constant; and two mechanical, the oscillation duration of the indicating instrument and its absorption. We can change these four values in order to lend to the equipment the characteristics, which make it as similar as possible to the ear.

We want to now try to derive from the literature data rules for the calculation whereby we may however expect more than approximate values.

After Steudel the value of an individual click increases up to a duration of 1 ms, in order to remain about constant beyond that value. The charging time constant must lie thus in the order of magnitude 1 ms.

An absorbed sine wave oscillation shows the transition from the click to the steady tone: In the case of very quick rise time practically we have another click, with slower rise time we have nearly the steady tone. Steudel had found that with a fading-away 1000 Hz tone the volume rose around 10 phons, if one increased the fading time constant from 1 ms to 100 ms, the click thus became a steady tone. The short single click thus lies in the evaluation around 10 phons below the steady tone of same peak voltage and the transition is approximately to 100 ms to be the same value. This results in a dependence shown in ***fig. 1*** of the indication on the duration of a pure tone. To reach this process leaves itself by a suitable fading time constant (about 350 ms) and a sufficiently slow-acting indicating instrument.

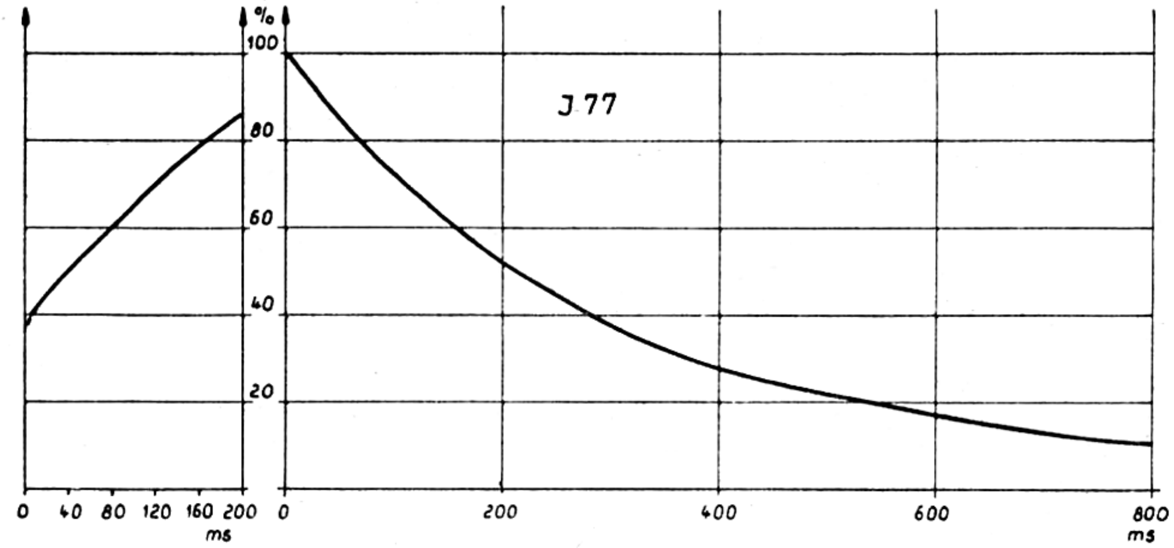

Abb. 1

Anzeige des J 77 in Abhängigkeit von der Länge eines Dauertones und Abklingvorgang nach Abschalten des Tones

Fig. 1 Indication of the J -77 as a function of the length steady tones and drop after switching off tones

How one sees direct, also rising the volume of clicks with the recurrence rate can be reached, if one selects the fading time constant so largely that between two impulses only a partial discharge of the condenser takes place. Thus the third substantial demand of Steudel would be fulfilled.

The procedure outlined here drove naturally only to one approximated correct indication. One will have to test such an equipment at typical noises and after the principles described above, make alterations.

The noise meter J 77

Equipment, which is developed according to this principle is the J 77 (Rel. 3 U 311/313 of the company Siemens & Halske), which for some time has been used as obligatory measuring instrument for noises and external voltages with the West German broadcast organizations, and which is also adopted by the Federal Post Office. It was developed, by connecting a U21 weighting filter before the level monitor and at the output in place of the light-beam instrument a slower-acting pointer-type instrument is used. The U 21 is a full wave peak detector with an averaging time of a few ms and a fading time constant of 350 ms. By use of a very high alternating voltage at the diode this is practically linearized. The indication is however approximately logarithmic.

Directly after this equipment appeared on the market, we submitted it in to the central technology bureau to an examination, by comparing its indication with the evaluation by 20 to 30 test subjects with different noises. The test subjects in addition heard six different disturbing noises (line noises, noise of two magnetic tape recorders, 1000-Hz-Tone, noise of a passing airplane and hammers on stone) by playing a tape recording, and each subject had the task to adjust by means of an automatic controller the level to same volume with a standard white noise to which they could switch alternatively.

Originally it was planned to capture both the volume and the degree of the annoyance. It was shown however that most observers did not make a difference between the two terms. Actually rather the interfering effect might have been described as the volume.

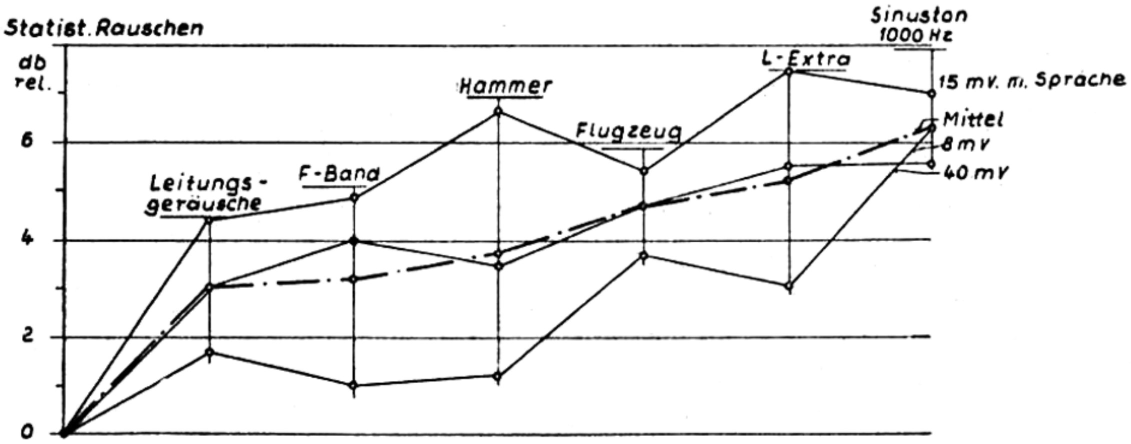

Abb. 2

J 77 in alter Ausführung mit Bewertungsfilter nach CCIF 1934. Anzeige des Gerätes bei Geräuschen, die als gleich laut empfunden werden

Fig. 2 J 77 in the old Version with weighting filters for CCIF 1934 Ad of the device in sounds that are perceived as equally loud???
"Statist Rauschen" = "extra noise"; "Leitungs - geräusche" = "line noises"; "Flugzeug" = "airplane"; "Sprache" = "speech".

The adjusted levels were compared with readings from the J 77. The results are in shown in *fig. 2*. (The lines connect here only measuring points of the same row, thus having no physical meaning.) It is noticeable that only positive values were described that all noises were felt to be more disturbing than the white noise which was felt less. In other words: The J 77 resulted in a too small indication for the white noise, that of all noises those with most energy in the highs showed relatively lower indications both in the case of the line noise and the noise of the F-bands, *["Rauschen des F-Bandes" – it is not clear what this means]* thus with all noises which exhibit a large portion of high frequencies. The high frequencies were therefore considered not sufficiently by the weighting filter. We asked the manufacturing firm to use another weighting filter than the CCIF 1934 one that was used. Today's execution of the J 77 uses the CCIF 1949 weighting filter and thus achieves the necessary stronger evaluation of the high frequencies.

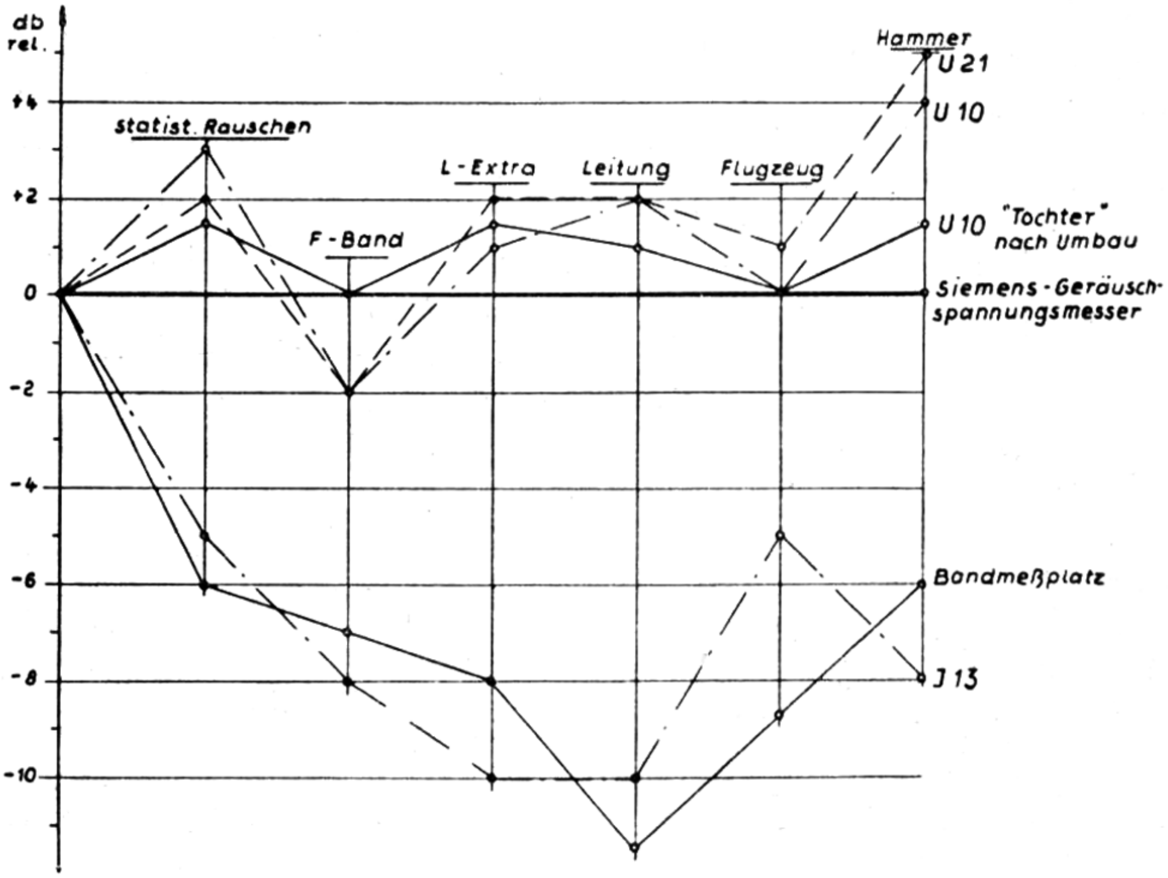

Abb. 3
Anzeige einiger Geräte im Vergleich mit der des J 77
(Vgl. das bei Abb. 2 Gesagte)

Fig. 3 Display of some devices in comparison with that of the J 77 (See fig. 2)

Finally the indication of the J 77 was compared with the indication of some other devices with the same noises. The deviations opposite the J 77 are represented in ***fig. 3***. For the measuring the indication for the 1000-Hz-Tone was used. There is at first sight two groups recognizably: The peak value instruments according to kind of the level monitors with define more briefly integration and long fading time essentially follow the J 77. The rms instruments and the peak detectors with long average times point however with some noises up to 10 dB lower indication, suggesting that the differences are principally due to the kind of rectification!

The J 77 permits besides the noise measurement also an unweighted measurement within the range to 20 kHz. This measuring range will generally be sufficient, only in special cases (stray effect of HF or tape recorder bias frequency) an examination with a vacuum tube voltmeter will be necessary. The upper border was specified on 20 kHz, in order still that crosstalk on the phantom circuits of unloaded carrier frequency cables will be captured. A uniform definition was anyway necessary, in order to receive finally once comparable measured values. Some voltmeters have completely arbitrary upper corner frequency rolloff.

> As the standardization of the measuring method the uniform designation is just as important. Also for it suggestions of the work commission measuring technique are present.
>
> Noise voltage should be described in the future only as the weighted measurement, external voltage as unweighted measurement. Both are to be indicated in dB, whereby voltages in dBu (0 dB = 0.775 V) are indicated, a voltage difference against it by dB (rel) should be marked. The interference voltage is a general heading and covers noise voltage and external voltage.

After evenly the saying the J 77 would have actually interference voltage measurers mean, since it we think, tells us that the noise voltage is actually substantial, ever more interspersed. The noise voltage is finally the thing which the listener is troubled by and which must be kept as small as possible. The external voltage however becomes only interesting if it entails an over-regulation of the system together with the operating signal or if it leads to disturbing indications with devices without frequency weighting, for instance the level monitor. Since this is not the case with any of today’s common devices, their measurement does not represent an evaluation of the equipment, but has only the sense that the equipment or the channel be checked to examine its operating ability. In pulse evaluation and the introduction of the CCIF curve of 1949 has measured the consequence that the noise voltage levels determined with J 77 lie usually substantially higher than those with the CCIF 1934 and the vacuum tube voltmeter. That led first to a certain uncertainty. Meanwhile it is only one question of the time, until one creates new guidelines on how to define a good enough noise margin. It was therefore also agreed upon that in the transition period with both devices are to be used in parallel. Since each noise signal has a completely special composition, both, which the portion of impulses and, which the portion that concerned, it is not possible for individual frequencies, to compare the old values with the new.

Fig. 4 shows a comparison with some other types of device.

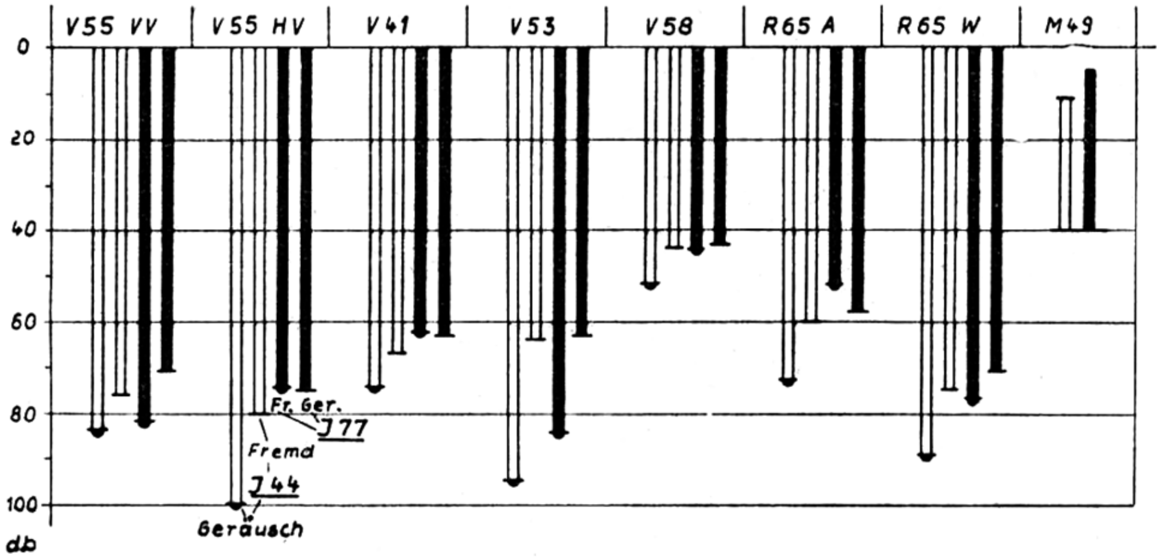

Abb. 4
Geräusch- und Fremdspannungswerte einiger Gerätetypen gemessen mit J 44 (CCIF 1934) und J 77 (CCIF 1949) (Vorläufige Meßergebnisse des Prüffeldes)

Fig. 4 Noise levels of external voltage values of some types of device measured with J 44 (CCIF1934) and J 77 (CCIF1949) (Provisional results of measurement of the test field)

The conversion from one measurement technique to another brings incontestably a substantial additional work with itself. It appears however more correct to take this trouble once than continuing to measure using a procedure which is incorrect and can steer new developments into inappropriate courses. So it could quite happen with the use of the old measuring procedure that the developer is concerned with reducing power supply hum still further while in reality, for example, to the ear it is more crucial to address a sharp noise of high frequency, as is caused by insufficiently shielded contacts.

Weighting curves

Some concern also arose that with the weighting curve of 1949 the noise level was evaluated more highly than the external voltage. Partially that was regarded even as proof for the unsuitability of this curve, since the ear is cannot hear nevertheless “any longer than the present”. One observes however that there is no physical or physiological relationship between the measured values of noise and external voltage. Both are rather only brought by the completely arbitrary appointment that the indication for the standard frequency of 1000 cycles per second should be the same, to each other in relationship. In principle one could have selected just as well the old standard frequency of 800 cycles per second or also any different one than point for comparison, whereby one would have come each time to another relationship of the measured values for noise and external voltage.

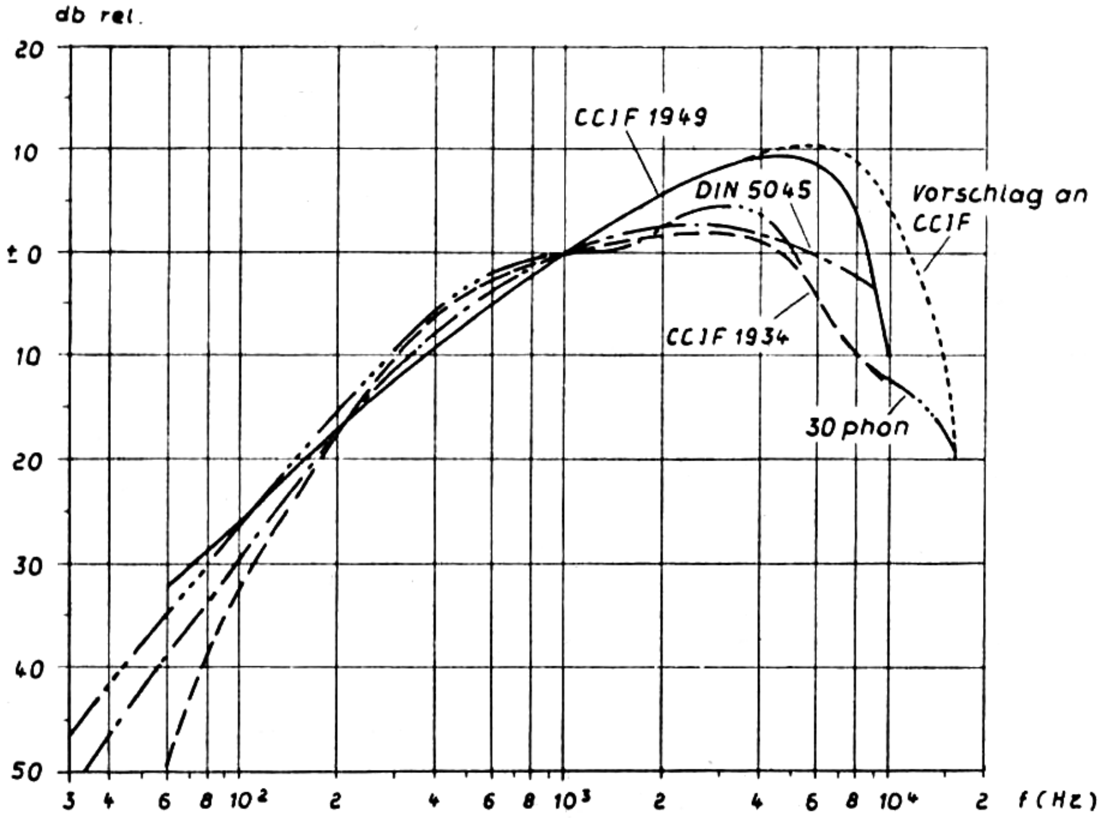

Abb. 5

Einige Bewertungskurven zur Geräuschspannungsmessung

Fig. 5 Some weighting curves of noise measurement

The discussion over which weighting curve (also Psophometer curve after the Greek word for noise) is the most suitable, is also today not yet completely final. The curves in ***fig. 5*** don’t contain however by any means all curves, which have been used in the course of time. The older tend, for instance the 30 phon curve indicate, very closely to the volume curves. One only later became attentive to the differences between volume and interfering effect. The crucial step takes place with the transition to the CCIF curve from 1949. It was based on investigations of AT&T, by which consciously one tried to determine the degree of the annoyance under conditions as they are present with the broadcast recording in private dwellings. The substantially more critical evaluation of the high frequencies resulted.

Also this curve is regarded however not as final, but designated by the CCIF as, “provisional recommendation". The CCIF has asked various organizations and the Federal Post Office, whether results of measurement are in agreement, as there is one alteration of this curve that may be desirable to make (question 15, Studying Committee III). On suggestion of the Federal Post Office thereupon the NWDR on behalf of the working group of the West German broadcasting corporations attempts to clarify this question.

Our Own attempts at defining the weighting curve

We aimed to follow the AT&T approach of accomplishing the observations if possible under the same conditions (utilizable volume, room level) experienced in listening to radio broadcasts at home.

The emphasis was put thereby in the critical cases, how they are present for example during the transmission of quiet places of high-quality music in quiet rooms. In order to be able, which arise to changes under deviating conditions, however also attempts in noisier areas and with somewhat less sensitive music measure were undertaken. As utilizable program material quiet recording of high-quality piano were selected and organ and string music motives with as small a dynamic range as possible, in order to keep the dispersion of the test results small due to varying volume of the signal level used. Each observer could regulate for himself the playback volume steplessly, as he normally hears listening to broadcasting.

The disturbing noise was radiated under accordingly natural conditions over the same loudspeaker. It consisted of a one-third octave band of random noise and a pure tone periodically interrupted with a frequency of 2 cycles per second, after the suggestion of the CCIF the frequencies 50, 100, 200, 400, 800, 1600, 3200, 6400, 8000 and 12500 cycles per second were used. It was observed that sensitivity was substantially higher in relation to high frequencies, than was to be expected after the CCIF 1949 curve, so there was a the closer investigation of this range in a second set of frequencies, which overlapped first in a larger frequency range in order that sufficiently many tests were done. The frequencies 3.5, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16 kHz were used. Within this range we measured with narrowly swept pure tones (sweep rate 6.25 cycles per second, frequency deviation 100 cycles per second), since the third-octave noise contains too wide a range for a clean measurement.

The interferences could be reduced by the test subjects by means of an adjustable attenuator in stages of 2.5 dB to the point that they did not judge the benefit of the presented music to be impaired.

Half of the attempts were accomplished in a quiet area of 30 phons noise level, the other half in a noisier area of 50 phons. Since such an area with approximately constant noise level was not available and strong temporal fluctuations would have increased the dispersion of the results of measurement unnecessarily, the level in a calmer area was artificially increased. To achieve this, in addition over a second loudspeaker a tape recording of the road noise of a busy street was played, whereby the upper frequency range was electrically reduced, in order to replicate sound absorption by closed windows.

The observations were implemented by 20 ladies and gentlemen at the age between 20 and 30 years. Their hearing had been examined before with a phonometer and cases of hearing loss had been excluded.

Before the attempts the observers were expressly asked to evaluate the interfering effect and not the audibility or the volume of the interferences.

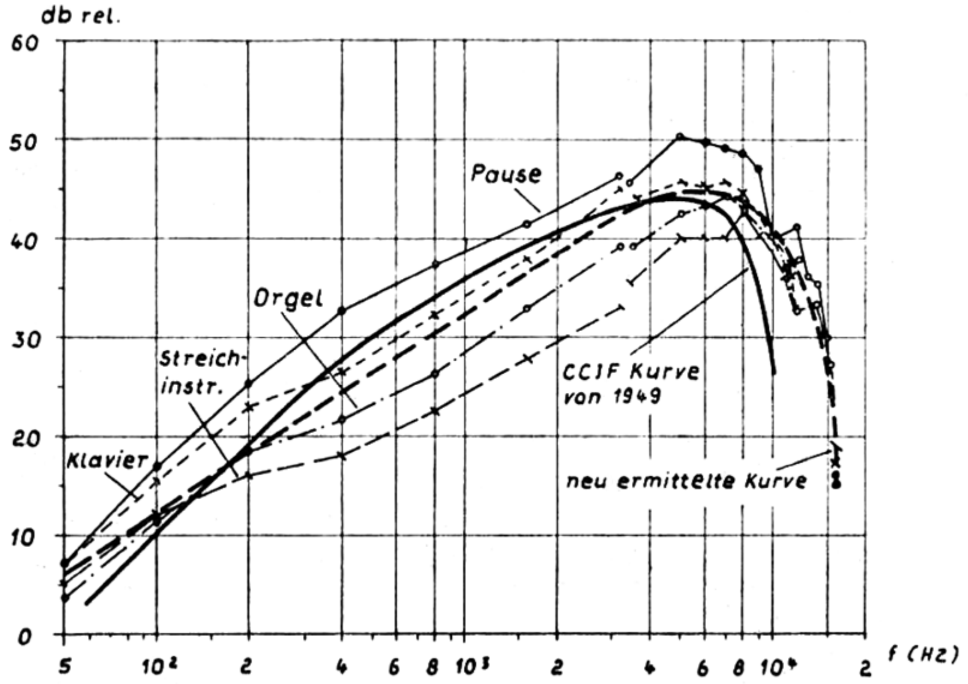

Abb. 6

Frequenzgang nach den Versuchen der Zentraltechnik bei verschiedener Nutzmodulation. Von der ZT vorgeschlagene Bewertungskurve im Vergleich mit der nach CCIF 1949

Fig. 6 Frequency range of the attempts of the central technology bureau test signals. Suggested by the weighting curve CCIF 1949.

The results of the attempts are presented in *fig. 6*. Thereby not only over all test subjects, but also over the two different ambient sound levels the interferences were averaged. An averaging over the presented noises was not made, because quite different opinions can be reached depending on the different noises. As to be expected, sensitivity is not much smaller in the modulation break at the largest versus the piano music with its pronounced intervals between the individual tones. If, as is with organ and string music the case, this correlation is missing, the masking effect of the presented noise is particularly stronger in the middle frequency range.

A similar effect has by the way the room ambient sound level, while the difference of the disturbing value of noises hardly affects itself. The strongly taken off curve (CCIF 1949) covers itself within the lower and middle range quite well with the results of the attempt, particularly if one regards the critical cases (pauses and piano music). Just as well one could use however the broken straight line with an upward slope of 6 dB per octave (simple RC element). Within the upper range the new measurements result in however a noticeably larger sensitivity. Here therefore the broken course of the curve was suggested. The not inconsiderable deviation is possibly to be attributed to the possibility that during the AT&T investigations also older test subjects were involved.

The necessary noise margin

The CCIF’s goal in the test series just described was only the appointment of the frequency response for a weighting filter. The investigation of the necessary signal-to-noise ratio took place in a second test series, since for this purpose the actually arising interferences promised a better approximation to practice as the somewhat artificial disturbing noises, which were necessary for the definition of the frequency response. The following eight noises were used:

1. Noise of amplifier (V 72).
2. Inductive stray effect of power supply hum. The 200 Hz component of powerline hum was subjectively crucial.
3. Switching noise of relays and power line hum on a line. For the ear the impact of impulsive switching noise was crucial.
4. Crosstalk of a long-distance call on a phone line. The well understandable woman’s voice outweighed all background noises.
5. Cross talk from accordion music on a line. The music, with which as consequence of the cross modulation the high frequencies were substantially overestimated, outweighed also here.
6. Noise of magnetic tape recorder (increased in volume). For the ear the frequency band around 4000 cycles per second was most strongly observed.
7. Noises in a VHF receiver. The noise consisted of a set of pure tones, which did not lie harmoniously to each other and for whose pitch continuously changes. The hearing-moderate impression was some high and unpleasant swirling or chirping.
8. Pure tone 1000 cycles per second. The tone was introduced particularly for calibration and measuring purposes.

In the remaining points the test procedure was maintained and only slight changes were introduced. Thus the string music used so far, which was quite obscure and compact and hardly differed in addition concerning its effect on selection was changed. Furthermore the artificial road noise was lowered from 50 to 40 phons, due in large part that many of the test subjects said that they would not listen to broadcast transmissions, and certainly no high-quality music with so loud a background noise.

The measurement of the interferences took place again in the sound field. This was necessary, in order to eliminate the inevitable remaining frequency response from room and loudspeaker. The complex nature of most natural interferences permits no computational correction, as was possible with the artificial interferences.

With very sharp impulsive noises some rounding of the signal is to be expected on the way to the loudspeaker, so that there may be some difference between the heard disturbance and the indication of the J 77's direct electrical measurement. It is to be expected however that this error is small due to the frequency response in relation to the deviations.

While for the determination of the frequency response the other characteristics (kind of detector, time constant) of the instrument take only a minor role they are of decisive importance when defining the required signal-to-noise ratio, since noises were used here, which result in very different measurements for steady tones and impulses. The measurements were accomplished therefore in parallel with the J 77 and with an rms instrument (thermocouple) according to at the time the still valid basic international standards. The comparison with the results of the subjective test permits then at the same time an evaluation of these measuring instruments concerning their suitability for the measurement of noise levels. One evaluated in both cases after CCIF 1949. In addition a comparative measurement with a J 77 was accomplished, with which the filter curve had been adapted to the process suggested by the time (stronger evaluation of the highs) by means of an upstream four-pole network.

Since many natural interferences are temporally not constant, but have considerable dynamics, in the case of slow-acting instruments a varying indication is given, which makes the measurement more difficult. During the available investigations the indication was used with the loud places, since these might be crucial for the interfering effect. Isolated points were however ignored, since only according to experience repeated impulses are felt as disturbing.

Since the weighted signal-to-noise ratio required depends on the sound level of the program material giving full rejection of the disturbance, the result of the attempts depends directly on the sound engineers' measurement of the program. Therefore several sound engineers were asked for their opinion, whether they could evaluate the level of the program material that was used. Fortunately the dispersion of their data was so small that the average measured value could be used as a basis for the tests.

Results of measurement

Fig. 7 shows the averages of the noise margin demanded by 12 test subjects. First the large differences, which were determined depending upon the program material, interference and room sound level , were a surprise. Thereby obviously the program material has the by far largest influence. That is all the more remarkable, than the program selections differ not at all so much from each other; in all cases it concerns high-quality and relatively quiet, transparent music.

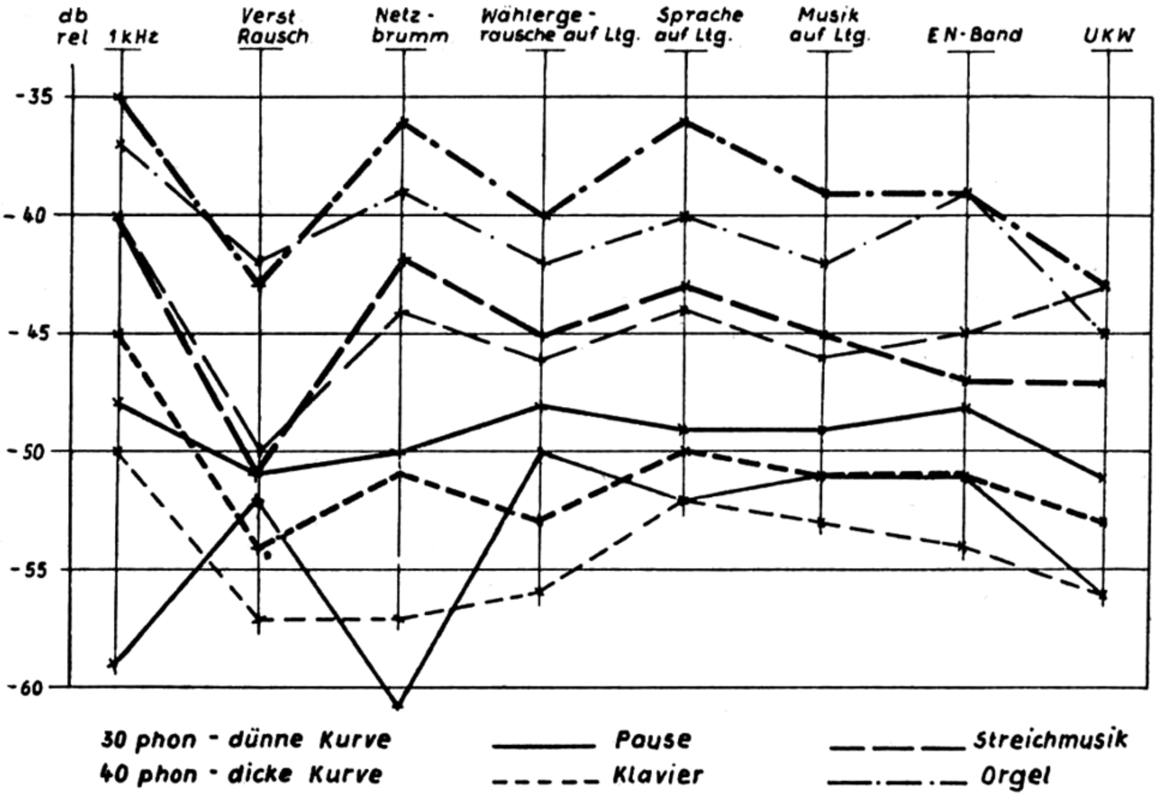

Abb. 7
Von den Versuchspersonen geforderter Geräuschspannungsabstand für verschiedene Nutzmodulationen und Raumgeräuschpegel

Fig. 7 Signal to noise ratio demanded by the test subjects depending on different disturbances and room ambient sound level

Pauses and piano music prove again as the most critical cases. The more transparent string music used here is however – contrary to the first recording – more sensitive to disturbance than the organ music. The differences in level correspond what was to be expected after the measurements for the psophometer curve. All interferences lie substantially in the middle frequency range, in which particularly in calm areas the evaluation curves for the individual kinds of music diverge strongly. Thus for example a mean of 13 dB results for the difference between piano and organ music from both test series.

The ambient room level brings generally only a total shift around 2 to 3 dB.

The values for different interferences within a series of measurements are rather constant, thus the evaluation by the J 77 follows the subjective breakdown impression well. Are remarkable the high requirements for attenuation of the steady tones (1000 cycles per second and power line hum) along with missing modulation (break) in calm areas. In presence of program material, in particular with organ and string music, these tones are very little disturbing. This probably corresponds to the experience that such tones are masked despite being audible, by a changing program content, because this obviously directs the attention of the listener more strongly on itself.

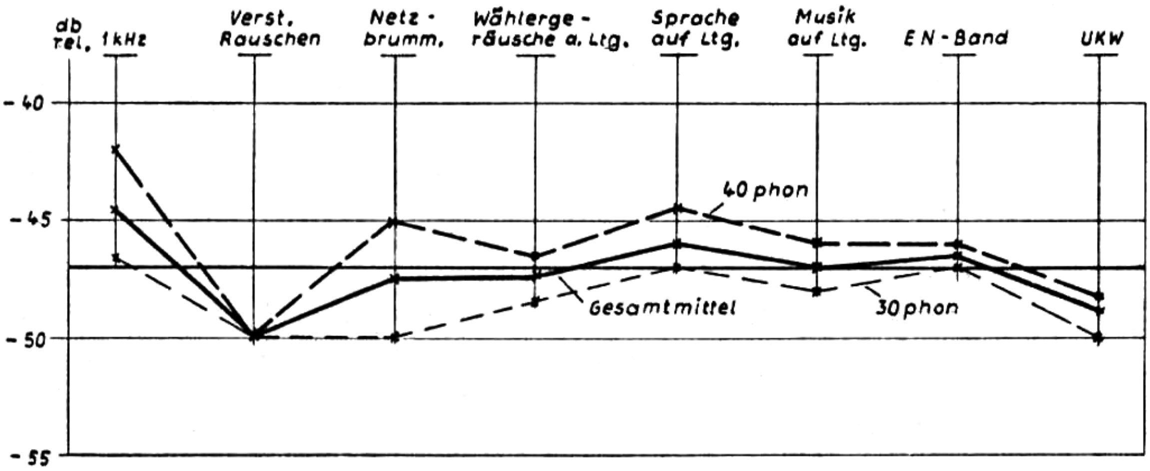

Abb. 8

Mittelwert über die Nutzmodulationsarten nach Abb. 7

Fig. 8 Average values over the disturbances of Fig 7

The average values in ***fig. 8*** shows still more clearly the good agreement of the measured values of the J 77 to those subjective evaluations.

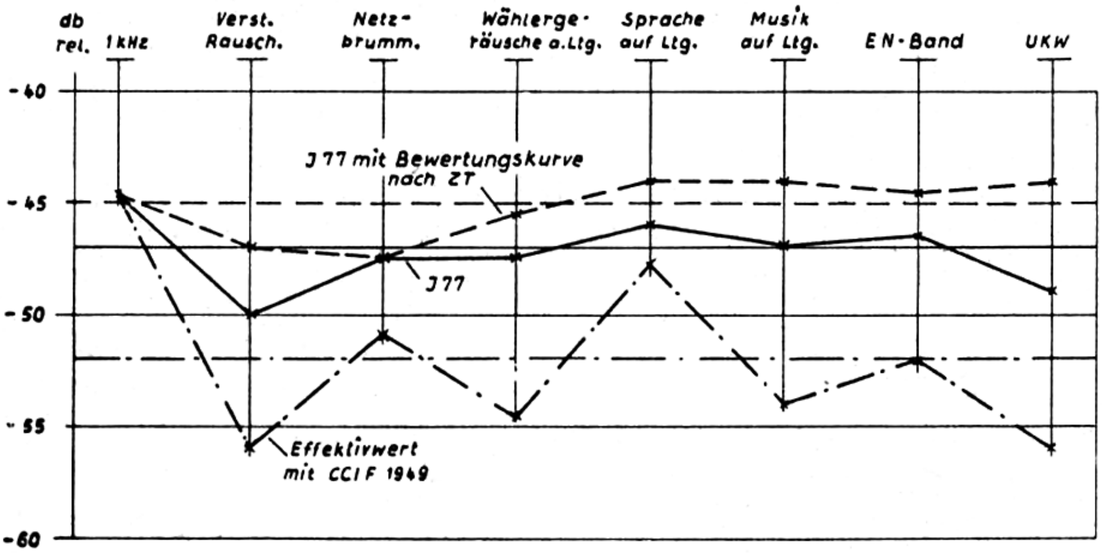

Abb. 9

Vergleich der Anzeigewerte eines J 77 (CCIF 1949) mit denen eines J 77 mit Bewertung nach dem Vorschlag der ZT sowie mit den Werten eines Effektivwertinstrumentes (CCIF 1949)

Fig. 9

The use of the weighting curve suggested by the time brings a further adjustment to the horizontal (***fig. 9***), thus certain improvement, if one wants to draw such conclusions from the available material, which is to serve predominantly different purposes. (Mean error 0.75 dB instead of 0.9 dB, mean error from subjective evaluation 0.65 dB.) There are substantial errors with the rms measurement, with up to 8 dB deviations from the average value (mean error 2.3 dB). Also this attempt speaks clearly for the superiority of the peak detector.

Attempt a conclusion

It lies in the nature of a demand for quality that thereby significant value must be granted to personal opinion – not least, because the implementation is often connected with a substantial economic expenditure.

In the available case it concerns above all, which program material is to be used for the test, and whether the listener with normal needs is to be the judge, or one with high requirements.

Furthermore – and this is probably the most difficult – the mental attitude of the test persons must be evaluated in terms of figures. This question is here far more important than during the definition of the psophometer curve for the disturbance, because that if such an influence is present depending on the program material, it cannot hardly be doubted that the frequency range of the disturbing influence is not well represented.

If we take as our principle accordingly, the most critical program as a basis, piano music in a quiet listening room, the evaluation, then we come on the average on 54 dB.

The group of fastidious music listeners required several dB higher signal-to-noise ratio. Such test subjects adjust to a substantially higher playback volume than the average. Since due to the nonlinear connection between audibility and volume the disturbing modulation is disproportionately strongly raised thereby, that leads to higher requirements for reduction of noise at the same time.

On the other hand we may however accept that the test subject, who expects a noise in order to be able to judge will be substantially more critical than the usual listener, who normally concentrates his attention on the program. The difference amounts to about 4 dB. The test subject is apparently first closer to the natural attitude and becomes more critical only later after an assessment is required. An interpretation in the sense that the listener becomes more sensitive with the duration of the disturbances, is less probable, since the character of the disturbance constantly changes. Also this would contradict the everyday experience that power line hum or a noise at the beginning of a transmission disturbs frequently, while one later in the program is often ignored completely.

With consideration of all of these circumstances one can conclude that a weighted signal-to-noise ratio of 55 dB is to be sought. Beyond that no further increase is to be represented, if it is connected with considerable costs. A margin of 45 dB might cause no impairment with most types of program material still cause no impairment, and even with 35 dB large parts of the program are still heard with satisfying quality.

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