ON LOUDNESS MATCHING (THIRD REPORT)

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Basic Standpoint of Loudness Matching

The attenuation-constant of the transmission system may be a quite clear idea, so long as we limit our sight within the objective side of the physical phenomena. The attenuation-frequency characteristics are also considered to give an exact, undisputable indices for communication circuit design. Moreover, we cannot but believe that the forms of its characteristics may give us some informations with concern in the merits of the system in question. But here we shall try to consider the fact on the most basic ground. The idea of attenuation in question must be based on the physical definition, making clear the relationship between physical quantities (such as, the power, voltage and current) on the analytical dimension (such as, pure sinusoidal oscillation of merely single frequency). In what relation can such a simple but exact (only in the physical sense) idea stand with the actual attenuating phenomena of the real, concrete, vital sounds which cannot be recombinated perhaps by means of the simple analytical methods? What does mean the physical idea of attenuation for the actual complex sounds of which are composed the real communicating signals ? What does still further mean the response-characteristics of communication systems to our aural sensation that, in fact, determines definitively the loudness of sounds? An insurpassable abyss seems to lie out of sight there. Now we are to attempt to bridge over the difficulty.

General Consideration on Transmission Effect

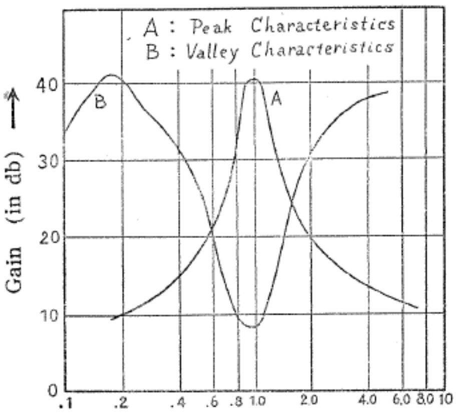
As real signal sounds in our research, we always take up not pure tones, but speech sounds because the former is considered merely as an analytical unit. Such being the sense of expression, we must give here precedence to the "sound-attenuation" without touching "tone-attenuation." For taking into account such sound-attenuation from the subjective side of human sensation, it will be convenient to apply the so-called comparative method, that makes a comparison of the test case with the reference one by the aid of aural sensation. Such consideration will lead us to the very idea of loudness matching. We can think, on the other hand, of the cases of volume matching, which represent the sound-attenuation by any objective procedure (such as by adopting VU meter, etc.). It should be one of the principal schemes of our investigation to inquire into what will be more preferable for the communicatory purpose of these two (subjective and objective) representations of sound-attenuation. But, for the time being, it will be more urgent for us to establish the methodology on the measurement of subjective character. It is because we can not help accepting that, in the present stage of its methodology, the subjective measrement based upon the psychometric principles can not stand in competition with the objective measurement in respect of the precision and reliability. Reflecting that the essentials of communication are originally of subjective phenomena, and that the estimation of *transmission effects* such as loudness-effect, pitch-effect, etc., and besides some quality-effects in higher order (articulation-effect, naturalness-effect and so on) are quite depending on the measurement of subjective nature, we shall engage ourselves in refining the subjective measurement, beginning with the work in field of loudness. The problem of loudness matching proposed here is, so to speak, a kind of subjective evaluation of the transmission effect of communication system, from the point of view of loudness property on signal sounds under transmission.

Outline of Experiment

As signal sound, we can take up many cases: continuous or discrete flow of speech sounds, and sustained or not-sustained single speech sounds in isolated state such as seen in phoneme unit. But in this study, only the continuous speech sounds are chosen.

Such steady flow of speech sounds supplied by consecutive readings of some convenient sentences, streams into the transmission systems under test, and thereafter is led before the testing subjects one after another at some constant rate of exposition aided by electronic switch.

As a transmission system, the two response-characteristics showing respectively peak and valley in form (shown in Fig. 1), are compared with the flat one as a reference (case X), and besides, three characteristics with different transmission frequency bands (but all in flat responses) are compared with the all-pass case as a reference (case Y). The attenuation characteristics of the filters used



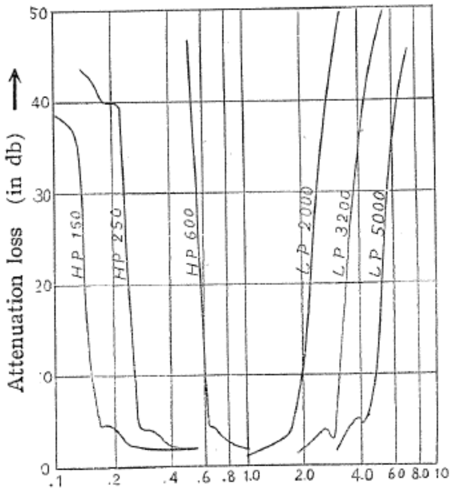


FIG. 1 (*left*). Frequency response characteristics of peak and valley types. The gain of valley system is shifted for illustration.

FIG. 2 (*right*). The attenuation characteristics of band-pass filters.

for restricting the band are shown in Fig. 2. As for the speech levels, 5 stages are established by adjusting the reproduction levels of the systems (case Z, not shown in detail here). According to the nature of the tests, a variety of combination is tried of three cases, a part of which is tabulated here:

X Case (as regards forms of response-characteristics)

P: Peak characteristics having its resonance point at 1000 c.p.s., with selectivity 2.0.
V: Valley characteristics having its anti-resonance point at 1000 c.p.s., with selectivity 1.8.
F: Flat characteristics, as a reference.

Y Case (regarding widths of transmission band)

W: With frequency band 150~5000 c.p.s. (5.05 in pitch octave).
M: With frequency band 250~3200 c.p.s. (3.68 in pitch octave).
N: With frequency band 600~2000 c.p.s. (1.74 in pitch octave).
R: All-pass, as a reference 70~10000 c.p.s. (7.16 in pitch octave).

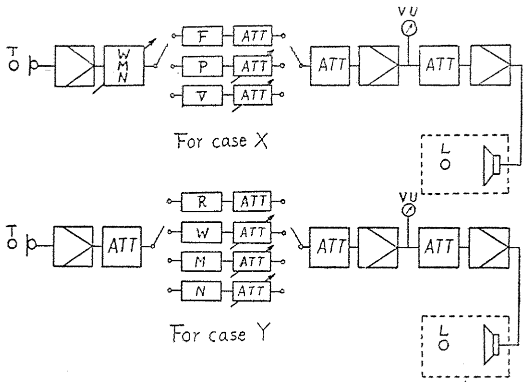


FIG. 3. Schematic diagram of equipment.

Signal → Case ↓	A	B
X	F (P)	P or V (V)
Y	R	W or M or N

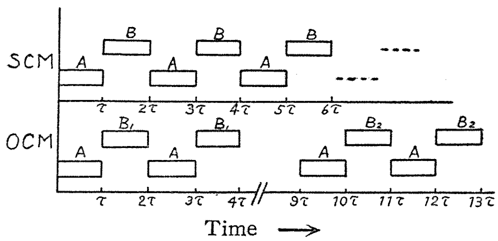
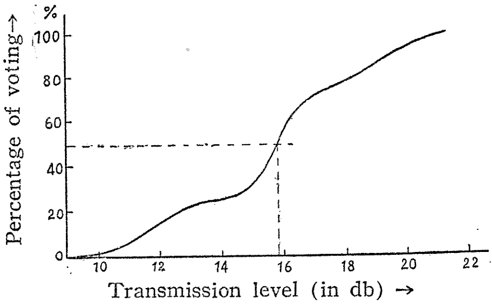


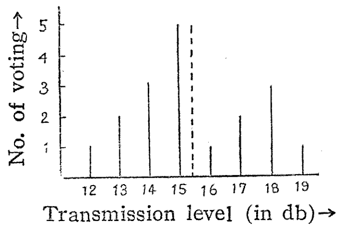
FIG. 4. Arrangement of stimulus presented to the subjects.

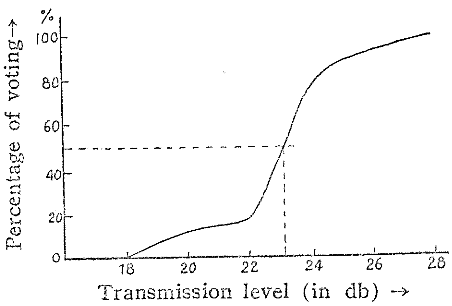
Two Principal Methods of Loudness Matching

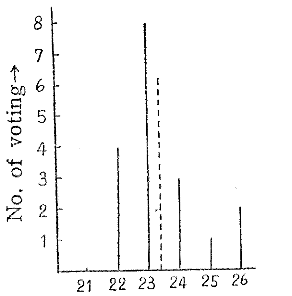
To perform the measurement on loudness matching, two principal methods are considered: operator-control method (OCM) and subject-control method (SCM). In the former, the levels prepared for the judgement of subjects are adjusted and operated by the experimenter's own hand and the subjects listening to the succession of a pair of signals, are requested to answer of the greater-or-smaller judgement of loudness between the two kinds of sounds (A and B) in a pair. In the latter, on the contrary, the subjects are charged to adjust by themselves the transmission level of test cases in such manner that keeps its balance with reference.

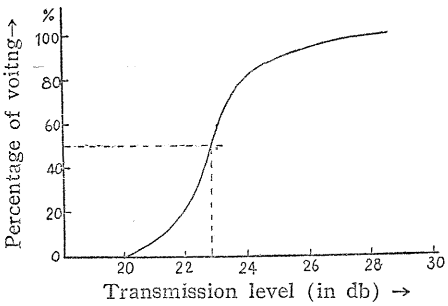
The results obtained by operator-control method are given in Figs. 5, 6 and 7. In this experiment, ten cases are so arranged that can differentiate one from another by 2 db intervals, each case accompanied with reference thus making a pair, and a flow of such pair series distributed in time in quite random order is brought to the subjects' ears. The determinations of *matched levels* in this case, are to set down the levels of test cases that correspond exactly to the positions of 50 per cent scores of judgement on the diagrams. As subjects, 3 young males, and











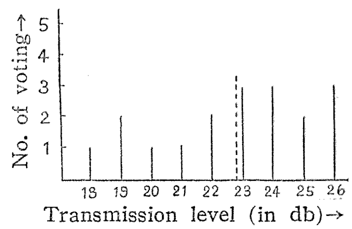


FIG 5 (*upper-left*). Results of loudness matching of F-P in operator-control method. The transmission band width is here 250∼3200 c.p.s.

FIG. 6 (*middle-left*). Results of loudness matchnig of F-V in operator-control method. The transmission band width is here 250∼3200 c.p.s.

FIG. 7 (*lower-left*). Results of loudness matching of P-V in operator-control method. The transmission band width is here 250∼3200 c.s.p.

FIG. 8 (*upper-right*). Similar to Fig. 5 for subject-control method

FIG. 9 (*middle-right*). Similar to Fig. 6 for subject-control method.

FIG. 10 (*lower-right*). Similar to Fig. 7 for subject-control method.

as talkers, also 3 males are employed. Here, combination of cases: in **M** type band (250∼3200 c.p.s.), **F-P**, **F-V** are taken where **F** as reference, and finally direct combination of case **P-V**. Each datum is obtained as a result from 20 times of observation.

The other results due to subject-control method are shown in Figs. 8, 9 and 10. In this test, exposition of signal materials composing the combination of the same conditions is continued until the subjects are convinced that the satisfactory adjustment is attained. So to speak, this SCM is to be carried out without placing any restriction on the (measuring) time required.

Taking a view of two kinds of results thus obtained, (by comparing respectively Fig. 5 with Fig. 8; Fig. 6 with Fig. 9; Fig. 7 with Fig. 10) we arrive at the conviction that the disparity of the mean values of matched levels due to the difference of testing methods appears at most on the order of 0.5 db as shown in Table 1.

TABLE 1

Methobs	Combination					
	F-P		F-V		P-V	
	$\overline{X}_{(db)}$	$S_{(db)}$	$\overline{X}_{(db)}$	$S_{(db)}$	$\overline{X}_{(db)}$	$S_{(db)}$
OCM	−0.1	2.55	+13.2	1.75	+12.5	1.49
SCM	−0.6	2.0	+13.4	1.2	+12.8	2.6

On Variances of Subjective Measurement by Two Methods

From Table 1, we obtain Fig. 11, which shows the tendencies of variances of measured data caused by two different testing methods in each three combinated case. Though there is little difference of the mean values of matched levels, there we find considerable difference in variance, that should deserve attention. The variance undergoes considerable changes thereby. Judging from the facts indicated in Fig. 11, we can suggest some certain tendencies:

(1) in case of combination **F-P** and **F-V**, SCM is preferable to OCM.

(2) in **F-V**, variances are almost minima, regardless of methods.

(3) in **P-V**, variances by SCM is far greater than that by OCM.

From these phenomena, we are going to give some explanation. According to the introspection of subjects, the unsimilarity of timbre between A and B sounds will bring about most remarkably in case **P-V**, and the resemblance of two timbres becomes most effective in **F-V** case.

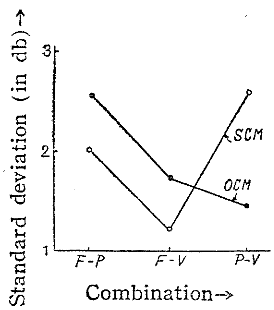


FIG. 11

If we assume here that the discrepancies in timbres have for effect an augmentation of the difficulties of loudness judgement (in fact we can ascertain it for the most part of cases), and moreover that the magnitude of variances can represent the degree of difficulties in such subjective measurement, we are able to suggest that at least SCM is more desirable than OCM in cases where the timbre resemblance is considerably established.

We suppose moreover that the psychical strain necessary for the subjective judgement will depend probably on the content of judgement; and with regard to judgement content, it is clear that OCM has more simple content than SCM and consequently that the psychical strain of subjects in case OCM will be less than that in SCM; this is consistent with the empirical fact that the subjects in SCM get tired sooner than in OCM; on the other hand, the timbre problem has an considerable effect on the judgement content in such loudness measurements; in accordance with the discrepancies of timbres, the loudness judgement becomes more and more difficult, and its variance also becomes more and more serious. This fact seems to explain the strange phenomena that SCM preferable in cases **F-P** and **F-V**, becomes rather unsuitable in **P-V** case.

(*Unfinished*)

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