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EFFECT OF ADDITIVE INTERFERENCE ON SPEECH TRANSMISSION

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This paper presents the relationship between logatom intelligibility of Polish speech and a level of masking random noise. Subjective measurements of intelligibility were carried out for optimal speech signal level 85 dBA and signal to noise ratio within a range from −15 dBA to +15 dBA. The influence of the frequency distortion (band limiting) was investigated for three cases of a band with: 100–6000 Hz, 400–2500 Hz and 300–3400 Hz. The obtained results are shown as a curve describing a relation between a logatom intelligibility and signal to noise ratio (S/N). The obtained characteristics were compared with a standard curve given in ISO Recommendation for a two-ears listening test.

1. Introduction

The present-day telecommunication networks offer a wide range of voice services based on different transmission systems. The rapid development of the digital technology has boosted the demand for the assessment of the influence of new transmission devices' parameters (transfer characteristics, coding techniques, etc.) on the quality of the speech signal transmission. The result of the speech transmission quality test or assessment also serves as a rating of the communication channel. Most of the studies concerned with the assessment of speech transmission quality concentrate on telephone communications.

One of the basic parameters of the speech signal transmission quality for analog and digital telecommunication channels, auditoriums and public-address systems and for the selection of hearing aids is the speech intelligibility. Despite of the considerable advances made in developing objective methods of measuring this parameter, the time-consuming and expensive subjective measurement of intelligibility or articulation, involving a specially trained group of listeners, still remains the only reliable method in this respect. Designers of speech transmission equipment and systems lean on objective measuring techniques, often disregarding the application limitations and the measuring accuracy that depends on the type of the tested object and the measuring conditions. However the ultimate verifier of the quality of the speech transmission equipment is its user — a human being — and the verification is made through subjective measurements of the transmission quality.

From among the different subjective techniques, going back to the beginning of the twentieth century, techniques which give directly (ACR) or indirectly (articulation and intelligibility measurements) a MOS rating on the five-grade quality scale are currently used [1, 2, 7–14, 17–19, 21]. An integral part of the applied method, regardless of the way in which the MOS rating is arrived at, should be a reference measure enabling the comparison and averaging of the MOS results obtained in different ways, in different media and for different languages.

Subjective measurement results should depend to the largest extent on the physical parameters of the tested transmission channel, but not on the structure of the language test. At the semantic level, the information is eliminated by means of logatom sets used to determine logatom or phonemic articulation. So logatom articulation averaged over a set of listeners, functioning as verifiers of the effectiveness of the objective method, is used as the reference measure of the transmission channel's quality.

When making subjective measurements of the speech transmission quality of a new piece of equipment or when verifying a new method of assessing the speech transmission quality, special care should be paid to the selection of the transmission conditions in the simulated telecommunication channel. Transmission conditions should be varied and the articulation values obtained should be uniformly distributed on the articulation scale. To determine the actual values of the interference parameters, one can use the relationship between the articulation and a single interfering factor. ISO recommendations [20] give a relationship, established for the band of 100–6000 Hz in binaural listening conditions, between the articulation (intelligibility) and the signal/noise ratio. In monaural listening conditions (e.g. a speech signal transmitted through the telephone chain), the ISO relation should be verified. Therefore investigations aimed at defining a relationship between the logatom articulation and a single interfering factor: white noise, pink noise, intelligible crosstalk and hum in monaural listening conditions, were carried out.

2. Measurement of logatom articulation

Subjective logatom articulation measurements by the conventional method are made in accordance with Polish the Standard PN 90/T-05100 "Analog Telephone Chains. Requirements and Methods of Measuring Logatom Articulation". [7].

Logatom articulation measurements are made at the actual operating conditions prevailing in the whole channel (in all of its individual elements) or at conditions imitating the actual operating conditions (kinds and levels of distortion, acoustic noise, etc.) in compliance with the requirements specified in the technical documentation concerning the particular devices which form the chain or its individual links. Individual links should be tested after they have been put in the place of the corresponding links in the model chain.

The measurement should be made in two acoustically insulated rooms: one functioning as the transmitting room and the other one being the receiving room. The level of the unintentional internal noise and the external interference in both the rooms should not exceed 40 dBA. If no requirements are specified for the background noise of the tested chain, the articulation should be measured at a noise level of 60 dBA in the receiving room and for the Hoth spectrum. Otherwise, the articulation should be measured at the room noise level specified in the requirements for a given chain or its single link.

The measurement of logatom articulation consists in transmitting logatom test lists read out by a speaker through the telecommunication channel; they are written down by the listeners, and then the correctness of the records is checked and the average logatom articulation is calculated from the relation (2.1) by a team of experts. It is recommended to use lists of 50 or 100 logatoms. Each list should be phonematically and structurally balanced.

Listeners should be selected from persons with normal hearing and normal experience in pronunciation in the test language. A person with normal hearing is a person whose auditory threshold does not exceed 10 dB for any frequency within a band from 125 Hz to 4000 Hz and 15 dB within a band from 4000 Hz to 6000 Hz. The examination of the hearing acuity should be made by means of a diagnostic audiometer. The size of the listening group should be large enough to ensure that the averaged test results obtained do not change as the group size is further increased. The minimum number is 5 listeners. The listening group should be well motivated.

The listening group which is taking part in the logatom articulation measurements should be subjected to a special training. The training should be conducted at the same transmission conditions at which the listening group will test the system and under different transmission conditions obtained by randomly changing the kind of interference and the signal/noise ratio. For any transmission conditions it is recommended to use a test material including at least two 100-item logatom lists or four 50-item logatom lists. Two or three training sessions should be held.

The logatoms should be emitted by speaking in even voice, clearly, without stressing the beginning of the logatom or vowels. The time interval between individual logatoms should allow the listener to record the received logatom at leisure. The recommended time interval between the emitting of each logatom is 3 – 5 seconds. The time interval between sessions should not be shorter than 24 hours and not longer than 3 days. The total duration of a session should not exceed 3 hours (including 10-minute rest periods after each 20-minute listening period).

Listeners record the received logatoms on a special form on which also the date of the test, the test list number, the speakers name or symbol (no.), the listener's name and additional information, which the measurement manager may need from the listener, are recorded. The record should be legible to prevent a wrong interpretation of the logatom. The received logatoms may be written in phonetic transcription (a group of specially trained listeners is needed for this) or in an orthographic form specific for a given language. A member of the team who checks the listening test lists calculates the number of correctly received logatoms for each listener and for each logatom list and then determines the average logatom articulation.

The average logatom articulation W_L, which specifies the quality of speech signal transmission for the particular transmission conditions, is calculated from relationship (2.1):

$$W_L = \frac{1}{N \cdot K} \sum_{n=1}^{N} \sum_{k=1}^{K} W_{n,k} \quad [\%], \tag{2.1}$$

where: N — number of listeners, K — number of transmitted test lists, $W_{n,k}$ — logatom articulation obtained from listening the k-th test list by the n-th listener and

$$W_{n,k} = \frac{P_{n,k}}{T_k} \cdot 100 \ [\%], \tag{2.2}$$

where $P_{n,k}$ — number of correctly received logatoms of the k-th test list by the n-th listener, T_k — number of transmitted logatoms of the k-th test list.

A measure of the scatter of the logatom articulation W_L in a set of listeners is the mean square deviation calculated from the following relation (2.3)

$$s = \left[\frac{1}{N \cdot K - 1} \sum_{n=1}^{N} \sum_{k=1}^{K} (W_{n,k} - W_L)^2 \right]^{1/2}. \tag{2.3}$$

If $|W_{n,k} - W_1| > 3s$, the particular measurement should be excluded from the calculation of the average articulation and W and s should be recalculated using relations (2.1) and (2.2) and taking into account the reduction in the number of measurement results. The results of subjective measurements of the logatom articulation should be included in the measurement report. The value of the average logatom articulation obtained can be used to determine the quality classes according to Table 1.

Table 1. Classes of speech articulation quality.

Quality class	Description of quality class	Logatom articulation standard [%]
I	Understanding transmitted speech without slightest concentration of attention and without subjectively detectable distortions of speech signal	above 75
II	Understanding transmitted speech without difficulty but with subjectively detectable distortions of speech	$60 \div 75$
III	Understanding transmitted speech with concentration of attention but without repetitions and return queries	$48 \div 60$
IV	Understanding transmitted speech with great concentration of attention and with repetitions and return queries	$25 \div 48$
V	It is impossible to fully understand transmitted speech (breakdown of communication)	to 25
For each quality class the lowest logatom articulation values are lowest admissible values		

3. Experiment

Subjective measurements of the logatom articulation were made within the frequency bands 100 – 6000 Hz and 400 – 2500 Hz and in the telephone band, i.e. 300-3400 Hz, for a signal/noise ratio interval of (-15dB, +15dB) [4 – 6]. The listening team was selected from the Wrocław University of Technology students with normal hearing. The qualification was based on audiometric tests. There were 12 persons in the team. Prior to the proper measurements, the listening team was subjected to a 6 - hour training (two 3 – h sessions). Four phonematically and structurally balanced 100-logatom lists per measuring point were used. The list was selected at random. Subjective measurements of the logatom articulation were carried out under conditions of monaural listening using electrodynamic receivers for the optimum speech signal level of 80 dB(A).

The optimal level of the speech signal was set according to (3.1):

$$L_{\text{op}}^{(1)} = L_{\text{op}}^{(2)} + \Delta L^{(1)} + \Delta L_t \quad [\text{dB}], \tag{3.1}$$

where $L_{\text{op}}^{(1)}$ — optimal level of the speech signal during the one-ear hearing by means of headphones, second ear covered, $L_{\text{op}}^{(2)}$ — optimal level of the speech signal during the two-ear hearing in the free field; that according to the research of MAJEWSKI and ZALEWSKI [15] has for the Polish speech the value of 70 dBA, $\Delta L^{(1)}$ — correction for one-ear hearing −3 dB, ΔL_t — correction for the source of the sound; for headphones, telephone receiver, etc. $\sim$ 6 dB

The adoption of the rule of one-ear hearing by means of headphones caused some technical and practical problems:

• which method should be used for the measurement of the level of the acoustic pressure in the ear of a listener [22, 23]?

• what is the characteristic of the frequency response of the headphone at real conditions of work, i.e. with the head of the listener.

It should be taken note of the fact, that the producers of headphones give characteristics of the frequency response taken under conditions that are very far from the real ones, namely within the band up to 3500 Hz it is done for transceiver with an artificial ear and over 3500 Hz in the free field. In connection with this, experimental research was done in order to find the mean effectiveness of the headphones at real conditions of working and defining the relationships between the effective value of the voltage and the level of the acoustic pressure reaching the ear of a listener.

First of all, measurements of the effectiveness of the headphones in the free field were made. They result in the selection of headphones which have been used in the subjective measurements (listening), i.e. the set of headphones with characteristics differing mostly from the mean one were rejected. For the selected headphones, measurements of the characteristics of effectiveness under real conditions were made. The measuring set-up is shown in Fig. 1.

The measurements were carried out in the studio of the Institute of Telecommunications and Acoustics of the Wrocław University of Technology. The probe was slipped between the headphone and the auricle of the listeners ear. The end of the probe was

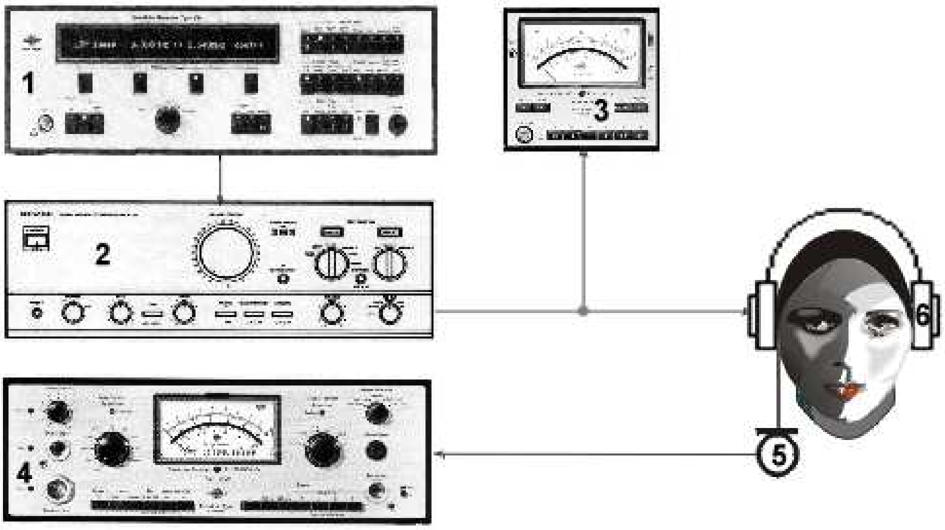

Fig. 1. The system of measurement of characteristics of effectiveness in real conditions of headphones placed on a real head. 1 – sinus/noise function generator B&K Type 1054, 2 – amplifier, 3 – measuring amplifier B&K Type 2609, 4 – sound level meter (measuring amplifier B&K Type2606), 5 – microphone (1/4 probe), 6 – real head.

at the inlet of the ear channel. The results of the measurements were used to obtain the mean effectiveness of the headphones for the real head (averaged over 4 real heads and 12 headphones used in the subjective measurements). The characteristic obtained is shown in Fig. 2.

The applied manner of preparing the sound material for the experiment demanded the knowledge of the relation between the effective value of the voltage and the level of the sound pressure reaching the ear of the listener. The measurements of the characteristics of the effectiveness of the headphones used in the logatom intelligibility measurements have shown that even characteristics in the band 100 – 4000 Hz cannot be assumed; they depend on the anatomic structure of the head and ear of the listener [3]. In connection with this, it was necessary to find the relation between the electrical value (effective value of the voltage) and the acoustic one (level of the sound pressure) separately for different types of signals used in the experiment (big irregularity of the frequency characteristic of the acoustic values causing the influence of the spectral features of the signal on the pressure level).

The measurements were performed for 10 headphones; each headphone was used for 5 real heads. The measurement system is shown in Fig. 1.

The mean values of measurement results with standard deviations for natural speech, white noise and pink noise are shown in Table 2. All the measurements were done for the "reference" band of 100 – 4000 Hz.

Different transmission conditions were simulated using a telecommunication channel MKT-1 model made in the Institute of Telecommunications and Acoustics of the Wrocław University of Technology.

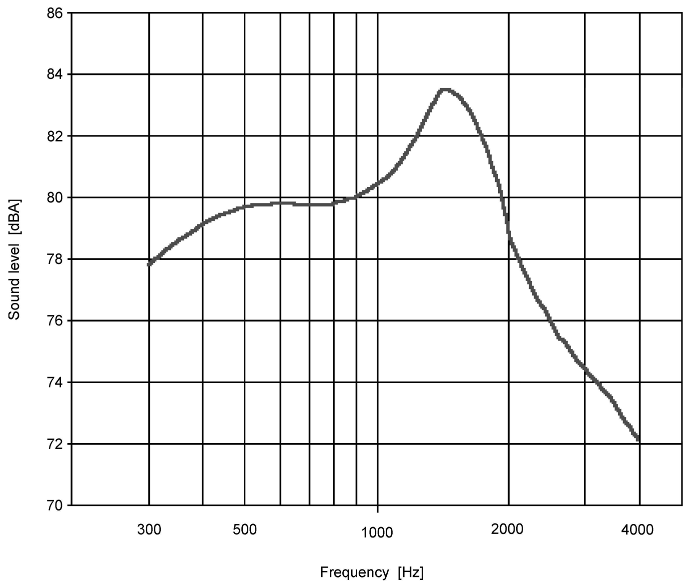

Fig. 2. The mean effectiveness of headphones used in subjective measurements for real head (results for 12 earphones and 4 heads).

Table 2. The relation between the level of sound pressure produced by headphones used in the experiment and effective value of signal voltage.

L [dBA]	U_{sb} [mV]	σ_{sb} [mV]	U_{sr} [mV]	σ_{sr} [mV]	U_m [mV]	σ_m [mV]
62	4.73	0.59	4.16	0.39	4.90	1.36
68	9.70	1.23	8.50	0.81	10.1	2.48
74	19.66	2.42	17.00	1.67	21.3	3.37
80	38.66	5.75	33.83	3.25	40.00	5.34
86	77.00	9.86	68.66	6.00	80.0	9.94

U_{sb} – mean value of effective voltage for white noise, U_{sr} – mean value of effective voltage for pink noise, U_m – mean value of effective voltage for speech, L – level of sound pressure, σ – a mean square deviation.

In the model the following interference and distortions can be introduced into the transmitted signal:

1. additive interference:
   a) white noise whose level is adjusted continuously,
   b) pink noise whose level is adjusted continuously,
   c) hum whose level is adjusted continuously,
   d) impulse interference with four different average values of the random distribution generating a time interval between successive pulses, whose amplitude is adjusted continuously;

2. frequency band limitation — 78 combinations set stepwise in a band of 100–4500 Hz and the so-called full band position; the limit frequency of the high-pass filter can be varied from 100 Hz to 500 Hz in steps of 100 Hz, whereas that of the low-pass filter can be changed from 2000 Hz to 4500 Hz in steps of 500 Hz; the full-band position represents a bandwidth of 100–6000 Hz;

3. attenuation-diagram linear distortions (9 independently switched on linear equalizers);

4. external interfering signals (intelligible crosstalk, unintelligible crosstalk, etc.); to introduce interference of this type a separate input for the adder had been included in the channel model.

The above possibilities of setting the telecommunication channel MKT-1 model's parameters permit the simulation of a large number of different speech signal analog transmission conditions that are reproducible and physically measurable.

In the presented experiment the effect of: white noise in the 100–6000 Hz, 400–2500 Hz and 300–3400 Hz bands, pink noise in the 100–6000 Hz and 400–2500 Hz bands, hum in the 400–2500 Hz band and intelligible crosstalk (for Polish and English) in the 400–2500 Hz band were studied. The crosstalk was produced by taping a text in Polish and English read by an announcer and then reproducing it during the articulation measurements. The reproduced text was inputted into the telecommunication channel MKT-1 model through the input assigned for external interfering signals. The speech and interfering signal levels were controlled by means of a 2606 Bruel & Kjaer measuring instrument; they have been measured in a logarithmic scale according to the correction curve A [22, 23]. The value of the speech signal voltage and the interfering signal rms values corresponding to values of the assumed sound intensity at the listener's ear were measured experimentally [3]. The results obtained are given in Table 2 which, beside the average logatom articulation W_L and the mean square deviation, includes the physical parameters of the telecommunication channel and the speech signal transmission conditions prevailing in it.

For a few randomly selected measuring points the distribution of the $W_{n,k}$ values were compared with the normal distribution. The agreement between the $W_{n,k}$ distribution and the normal distribution was tested by applying the Ko?mogorow-Smirnow test [16]. It has been found that at the significance level $\alpha = 0.05$, there are no reasons to reject the hypothesis of the goodness of the fit of the distributions. Thus it is reasonable to use the average logatom hypothesis W_L as an estimator of the logatom articulation for a given measuring point.

4. Conclusion

The subjective logatom articulation measurement results given in Table 3, obtained for 80 different speech signal transmission conditions, are presented graphically in Fig. 3.

The curves, representing the relationship between the logatom articulation and the signal/noise ratio for different transmission conditions, were approximated by a third-degree polynomial calculated on the basis of the least-squarees method. The relations

Table 3. Transmission conditions parameters and logatom articulation measurement results.

No.	ΔF [Hz]	S/N [dB]	S/P [dB]	S/P_{rz} [dB]	Remarks	W_L [%]	S [%]
1	2	3	4	5	6	7	8
1	100–6000	+15	–	–	sb	96.7	3.2
2	100–6000	+9	–	–	sb	86.0	2.8
3	100–6000	+6	–	–	sb	76.4	3.4
4	100–6000	+3	–	–	sb	63.3	4.2
5	100–6000	0	–	–	sb	49.0	2.5
6	100–6000	−3	–	–	sb	34.3	3.8
7	100–6000	−6	–	–	sb	21.4	3.1
8	100–6000	−9	–	–	sb	9.8	2.8
9	100–6000	−15	–	–	sb	3.8	2.1
10	100–6000	+15	–	–	sr	81.4	5.2
11	100–6000	+12	–	–	sr	79.3	3.4
12	100–6000	+9	–	–	sr	74.8	4.2
13	100–6000	+6	–	–	sr	66.0	3.3
14	100–6000	+3	–	–	sr	55.2	2.3
15	100–6000	0	–	–	sr	45.0	2.7
16	100–6000	−3	–	–	sr	32.8	3.0
17	100–6000	−6	–	–	sr	20.4	2.5
18	100–6000	−9	–	–	sr	10.5	2.2
19	100–6000	−12	–	–	sr	4.9	1.6
20	300–3400	+15	–	–	sb	95.1	2.0
21	300–3400	+12	–	–	sb	91.8	3.2
22	300–3400	+9	–	–	sb	85.5	3.8
23	300–3400	+6	–	–	sb	75.0	4.2
24	300–3400	+3	–	–	sb	69.1	3.5
25	300–3400	0	–	–	sb	55.0	3.8
26	300–3400	−3	–	–	sb	40.0	5.6
27	300–3400	−6	–	–	sb	23.0	2.5
28	300–3400	−9	–	–	sb	14.0	2.9
29	300–3400	−12	–	–	sb	8.0	2.2
30	400–2500	+15	–	–	sb	90.3	3.4
31	400–2500	+12	–	–	sb	87.5	2.6
32	400–2500	+9	–	–	sb	83.1	4.3
33	400–2500	+6	–	–	sb	74.6	3.0
34	400–2500	+3	–	–	sb	63.8	6.4

Table 3 [cont.]

1	2	3	4	5	6	7	8
35	400–2500	0	–	–	sb	51.5	6.2
36	400–2500	−3	–	–	sb	42.4	7.1
37	400–2500	−6	–	–	sb	26.1	4.8
38	400–2500	−9	–	–	sb	15.8	4.3
39	400–2500	−12	–	–	sb	9.1	2.8
40	400–2500	+15	–	–	sr	85.4	4.1
41	400–2500	+12	–	–	sr	82.8	2.7
42	400–2500	+9	–	–	sr	79.2	3.7
43	400–2500	+6	–	–	sr	73.6	3.6
44	400–2500	+3	–	–	sr	65.3	4.1
45	400–2500	0	–	–	sr	56.2	5.3
46	400–2500	−3	–	–	sr	45.7	3.4
47	400–2500	−6	–	–	sr	35.4	2.2
48	400–2500	−9	–	–	sr	26.2	2.9
49	400–2500	−12	–	–	sr	19.2	2.8
50	400–2500	–	+15	–	–	98.0	6.3
51	400–2500	–	+12	–	–	97.1	5.5
52	400–2500	–	+9	–	–	96.0	5.9
53	400–2500	–	+6	–	–	94.9	3.6
54	400–2500	–	+3	–	–	94.0	4.1
55	400–2500	–	0	–	–	90.0	5.3
56	400–2500	–	−3	–	–	82.7	4.6
57	400–2500	–	−6	–	–	71.8	3.3
58	400–2500	–	−9	–	–	53.8	3.8
59	400–2500	–	−12	–	–	24.3	2.2
60	400–2500	–	−15	–	–	3.0	1.3
61	400–2500	–	–	+15	pzp	97.5	4.3
62	400–2500	–	–	+12	pzp	96.1	3.2
63	400–2500	–	–	+9	pzp	95.2	3.9
64	400–2500	–	–	+6	pzp	92.5	4.2
65	400–2500	–	–	+3	pzp	90.1	3.1
66	400–2500	–	–	0	pzp	85.4	3.5
67	400–2500	–	–	−3	pzp	78.6	6.8
68	400–2500	–	–	−6	pzp	68.1	6.6
69	400–2500	–	–	−9	pzp	56.2	6.0

Table 3 [cont.]

1	2	3	4	5	6	7	8
70	400–2500	–	–	−12	pzp	37.4	5.2
71	400–2500	–	–	+15	pza	95.0	4.3
72	400–2500	–	–	+12	pza	91.9	3.9
73	400–2500	–	–	+9	pza	90.1	2.8
74	400–2500	–	–	+6	pza	87.4	3.0
75	400–2500	–	–	+3	pza	85.0	4.3
76	400–2500	–	–	0	pza	80.8	5.9
77	400–2500	–	–	−3	pza	73.9	6.9
78	400–2500	–	–	−6	pza	64.5	5.0
79	400–2500	–	–	−9	pza	51.2	3.3
80	400–2500	–	–	−12	pza	33.1	3.9

S/N – signal/noise ratio, $S/P_{\sim}$ – signal/hum ratio, S/P_{rz} – signal/crosstalk ratio, ΔF – frequency band, *sb* – white noise, *sr* – pink noise, *pzp* – intelligible crosstalk (Polish), *pza* – intelligible crosstalk (English), W_L – logatom articulation, s – mean square deviation.

Table 4. Relationship between logatom articulation and signal/noise ratio for different speech signal transmission conditions (signal/noise (S/N) ratio expressed in dB) W_L.

Transmission condition	Relationship $W_L = f(S/N)$ [%]	Correlation coefficient R^2
ISO recommendations	$W_L = -0.0071(S/N)^3 - 0.0044(S/N)^2 + 4.8119(S/N) + 49.997$	0.9995
100–6000 Hz, white noise	$W_L = -0.0072(S/N)^3 - 0.0018(S/N)^2 + 4.7943(S/N) + 48.695$	0.9997
100–600 Hz, pink noise	$W_L = -0.0058(S/N)^3 - 0.0139(S/N)^2 + 3.9803(S/N) + 44.079$	0.9995
300–3400 Hz, white noise	$W_L = -0.0063(S/N)^3 - 0.0221(S/N)^2 + 4.4923(S/N) + 52.723$	0.9957
400-2500 Hz, white noise	$W_L = -0.0053(S/N)^3 - 0.0261(S/N)^2 + 4.0964(S/N) + 52.052$	0.9984
400–2500 Hz, pink noise	$W_L = -0.0037(S/N)^3 - 0.0307(S/N)^2 + 3.2437(S/N) + 55.644$	0.9995
400–2500 Hz, hum	$W_L = 0.0057(S/N)^3 - 0.1811(S/N)^2 + 1.9644(S/N) + 89.531$	0.9999
400–2500 Hz, crosstalk (Polish)	$W_L = 0.0038(S/N)^3 - 0.1285(S/N)^2 + 1.8817(S/N) + 85.432$	0.9995
400–2500 Hz, crosstalk (English)	$W_L = 0.0052(S/N)^3 - 0.1281(S/N)^2 + 1.6945(S/N) + 80.958$	0.9994

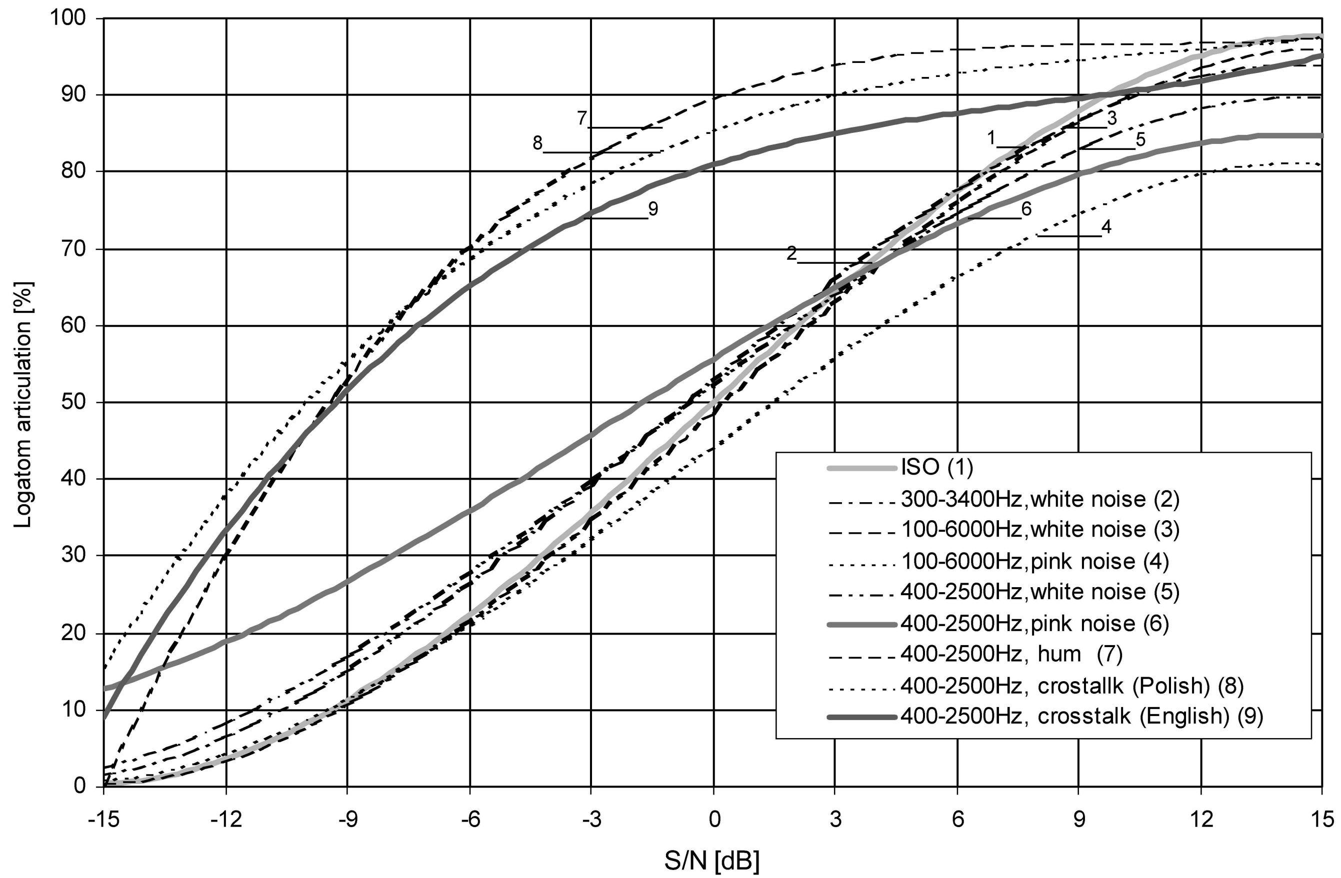

Fig. 3. Relationship between logatom articulation and signal/noise ratio for different speech signal transmission conditions: curve 1 — according to ISO recommendations; 2 – frequency band of 100-6000 Hz, white noise interference; 3 – frequency band of 100-6000 Hz, pink noise interference; 4 – frequency band of 300-3400 Hz, white noise interference; 5 – frequency band of 400-2500 Hz, white noise interference; 6 – frequency band of 400-2500 Hz, pink noise interference; 7 – frequency band of 400-2500 Hz, hum interference; 8 – frequency band of 400-2500 Hz, intelligible crosstalk (Polish); 9 – frequency band of 400-2500 Hz, intelligible crosstalk (English).

obtained are given in Table 4 which also includes values of the correlation coefficient R^2 — a measure of the conformity between the polynomial and the results obtained from the subjective tests. As one can see, there is very good agreement between the calculated curve and the empirical results; the value of the correlation coefficient R^2 exceeds 0.99 in each case.

The results of subjective logatom articulation measurements presented here can be very useful in determining the different speech transmission conditions when verifying a new method of measuring the speech transmission quality or evaluating a new piece of equipment designed for speech transmission.

The relations obtained are applied in the Institute of Telecommunications and Acoustics of the Wrocław University of Technology of designing subjective tests for the verification of results yielded by a new fully-automated subjective method of assessing the speech transmission quality and by an objective method based on the automatic speech recognition techniques.

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