The Study of the Performance of Speech Intelligibility Sentence in Serbian Language

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ABSTRACT: *We have characterized the Serbian language Matric Sentences using a test called as SMST. Sentences from the SMST base were used to test the influence of various types of Industrial noise to the performance SMST for SNR = 15 ÷ 10dB, on the people with normal hearing. Then we have given the experimental results using tabular and graphical format. We then did the comparison of analysis with Babble and Gaussian noise and comparisons with the International Standard IEC 60268-16. We have proved in the conclusion part about the intelligibility of speech.*

Keywords: Intelligibility of Speech, Industrial Noise, Matrix Test, MOS Test

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1. Introduction

In the digital communication, testing speech intelligibility has two aims. First is to give an evaluation of hearing disorders and second is the evaluation of speech transmission systems and speech synthesis. In this purpose it has been developed different kinds of tests: a) Logatom [1] and b) Sentences test (Harvard sentences [2], Plomp sentence test [3] and matrix test [4]).

Logatom test are test that use logatom - word without meaning, composed of consonant (C) and vocal (V) [1].

Harvard sentences are a set of standardized sets of words for testing speech [2].

Plomp sentence test is test which use sentences from everyday speech. In this test, semantically structure of sentence is good, but disadvantage of this test is that the examinees can logical guess the word and thus can affect on the test results [3].

Matrix sentence test are test that using defined syntax structure (name, verb, number, adjective and object). The combination of words leads to a large number of possible sentences, and sentence may be illogical in the semantic way. Matrix sentence tests are developed for: Swedish [4], French [5], Spanish [6], i.e.

Following the example of the first matrix test developed for the Swedish language by Hagerman 1982 [4], the authors have formed the base of Serbian Matrix Sentence Test (SMST) [7], for testing performance of speech intelligibility - sentences and words in the Serbian language.

In this paper, experiment was performed with the aim to gave a objective evaluation of performance SMST base in the presence of different types of the Industrial Noise. The experiment is organized in few steps: a) sentences are formed from the SMST base which are superimposed one of the types of industrial noise; b) the signal was degraded for value *SNR* = {-15, -10, -5, -2, 0, 5, 10} dB and c) testing was performed using open MOS test on a test group.

The comparative analysis of the results of experiment with Babble and Gaussian noise and International Standard IEC 60268-16: 2011 leads to the conclusion of the intelligibility of speech.

This paper is organized as follows. In the Section 2 is a description the SMST base and her phonetically structure. Section 3 shows experimental results speech intelligibility using sentences from the Serbian MST with the influence of the Industrial noise for different value *SNR* = {10, 5, 0, -2, -5, -10, -15} dB. Section 4 represents the conclusion.

2. Serbian Matrix Sentence Test

The SMST base contains 10 name, 10 verb, 10 numbers, 10 adjectives and 10 objects, as it is shown in the Table 1 [7]. Sentences of the matrix tests have a defined syntax structure, with precise word order: name, verb, number, adjective, object. Combination of the word from the SMST base gives 100000 sentences appropriate for testing performance of intelligibility of speech.

Name	Verb	Number	Adjective	Object
Slaviša	keep	eight hundred	expensive	books
Tamara	buys	seventy	red	apple
Gordana	has	sixteen	clean	tables
Tomislav	makes	fifteen	big	houses
Jasmina	wants	ten	cheap	gloves
Miodrag	sees	nine	different	ships
Marina	gives	eight	yellow	chairs
Dragoslav	sales	seven	new	armchair
Miroslav	clears	six	old	closet
Danica	likes	five	nice	flowers

Table 1. Serbian matrix sentence test

2.1 Phonetic Structure of the Speech Material

Phonetic structure and occurrence of phonemes, of the speech material base is shown in Figure 1.

To confirm the validity of phonetic structure and occurrence of phonemes in the SMST base (graphically shown with (-o-)) as a reference, for comparations, are analyzed significant literary works: the novels “Bridge on the Drina” by Ivo Andri (- □ -) and “Bakonja fra Brne” Sima Matavulj (- ∇ -), epics “The Mountain wreath” (-◊-), by Petar Petrovi Njegoš and drama “Koštana” (- Δ -) author Bora Stankovi.

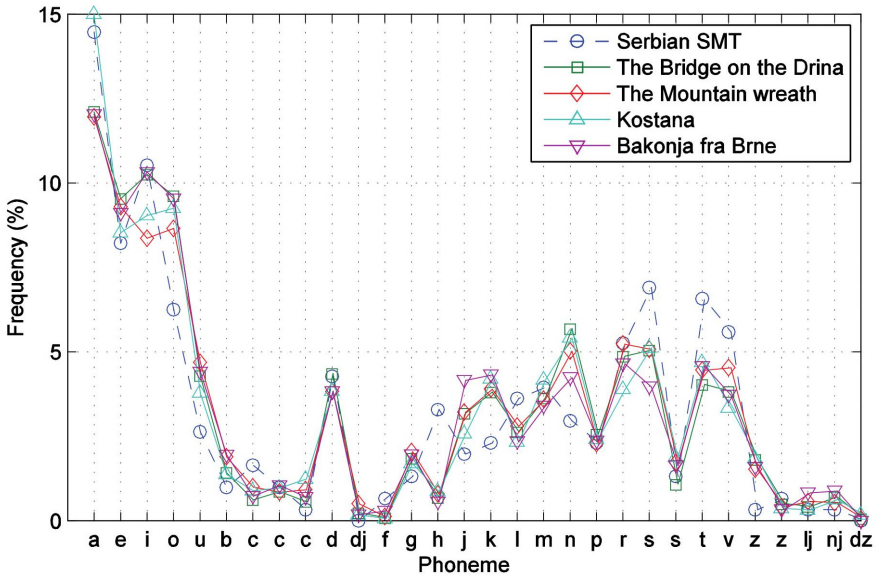


Figure 1. Phonemic occurrence phonemes Serbian MST (- o -), "Bridge on the Drina" (- □ -), "The Mountain wreath" (-◊-), 3 Koštana3 (- Δ -), 3 Bakonja fra Brne3 (- ∇ -)

From the Figure 1 it can be seen that the frequency occurrence of phonemes SMST base a well follows the occurrence of phonemes in the reference literary works, what leads the conclusion that the SMST base is suitable for testing.

3. Experimental Results and Analysis

The aim of experiment is to determine the influence of different types of industrial noise on the performance of speech intelligibility SMST base.

3.1 Experiment

The experiment consists of two parts. In the first part was formed generated signal y. This generated signal is obtained by superposing Industrial noise IN and the speech signal from SMST base x (Figure 2). Thus obtained signal $y = x + k.n$ is change the parameter values SNR in the range from -15 ÷ 10 dB.

The second part of the experiment is performing the using MOS test intelligibility on the test group. Testing was implemented in a acoustic ambient suitable for testing, and the examinees are listened reproduced signal y, through the headphones. Examinees would then repeated reproduced signal as they heard and understood, and the examiner are compare answer with the printed sentence on the screen (one of 100000) and note down correct answer to the sentence level and at the level of certain types of words (names, verb, numbers, adjectives and objects). Based on the obtained results it was performed the statistical analysis in order to determine the intelligibility speech. The results were analyzed by percentage in the range of 0 ÷ 100%.

At the end of analysis of results it was performed the comparative analysis of intelligibility of speech in the presence of Industrial (from this work), Gaussian and Babble noise (the results of [6]). A comparative analysis of intelligibility of speech in the presence Industrial, Gaussian and Babble noise leads to the conclusion that the best intelligibility of speech at Industrial, and the lowest at Babble Noise.

The block diagram of the generated speech signal $\boldsymbol{y}$ is graphically shown on Figure 2. Speech signal generated from the base SMST is represented by $\boldsymbol{x}$, and $\boldsymbol{IN}$ represented generated Industrial noise obtained from the base Industrial noise. Coefficient for determining a parameter value SNR is marked with $\boldsymbol{k}$.

3.2 Base

For the purposes of the experiment were formed following bases:

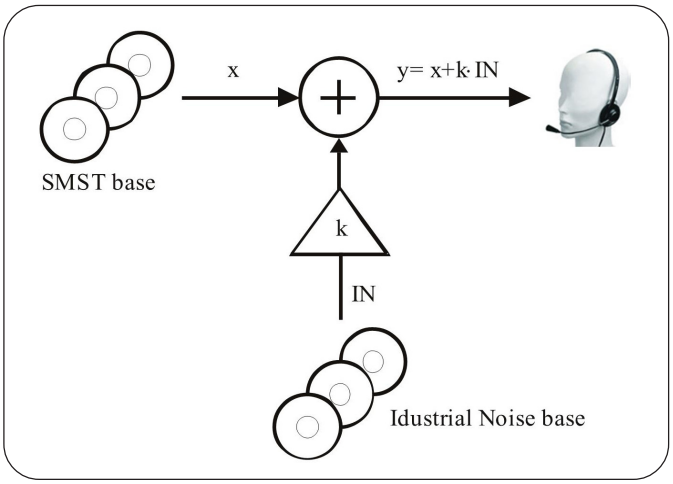


Figure 2. Block diagram of the generated signal *y*, formed for testing intelligibility of performance SMST using MOS test

- SMST base - words spoken in Serbian language, formed at the College of Applied Technical Sciences of Niš,
- Base of Industrial noise noise and
- Test group for MOS test.

3.2.1 SMST Base

From the material of SMST base, by random law, was obtained speech material base for testing. SMST base was recorded with a appropriate standard equipment. Recorded speech material is remembered in wav format on the hard disk on the computer. Sampling the speech signal is carried out at a frequency *fs* = 44.1 kHz and 16 bps [8]. After the program selected sentence for the MOS test, the sentence was printed on the screen, and it was visible only to the examiner.

3.2.2 Base of Industrial Noise

Base of Industrial noise consists of 4 types (noises are created from the different tools - Hilti for concrete, Drill for concrete, Drill and Sander), which are superimposed to the sentences selected from the SMST base. Figure 3 are represent the time characteristics (segment for the duration of 12 ms) and spectral characteristics Industrial noise for all type of Industrial noise.

3.2.3 The Test Group

The test group was formed from students of the College of Applied Technical Science in Nis (14 males and 14 females), aged between 19 ÷ 32.

Testing performance of speech intelligibility was done using open MOS test. The examinee is listened reproduced generated signal through headphones, after which he/she repeated aloud what he/she thought to heard and understood. The examiner compared answer with the sentence printed on the screen, and recorded the correct answer to the sentence level and at the level type of word (names, verbs, numbers, adjectives and objects).

3.3 The Results

Table 2 ÷ 4 shows the intelligibility of performance SMST with influence of the various types Industrial noise (Hilti for concrete, Drill for concrete, Drill and Sander) of the entire sentence, as well as types of the words for SNR= {-15, -10, -5, -2, 0, 5, 10} dB. Table 7 shows the intelligibility of the entire sentence, as well as types of the words in the presence of the Industrial, Gaussian and Babble noise [8] for value of SNR = {-5, -2, 0} dB.

3.4 Analysis the Results

Based on the results shown in Table 3 ÷ 4 and Figure 4 it can be concluded that intelligibility of type of word:

- *'Name' is best for* -5dB for Drill (100%), *and the worst for* -15dB for Hilti for concrete (25%),

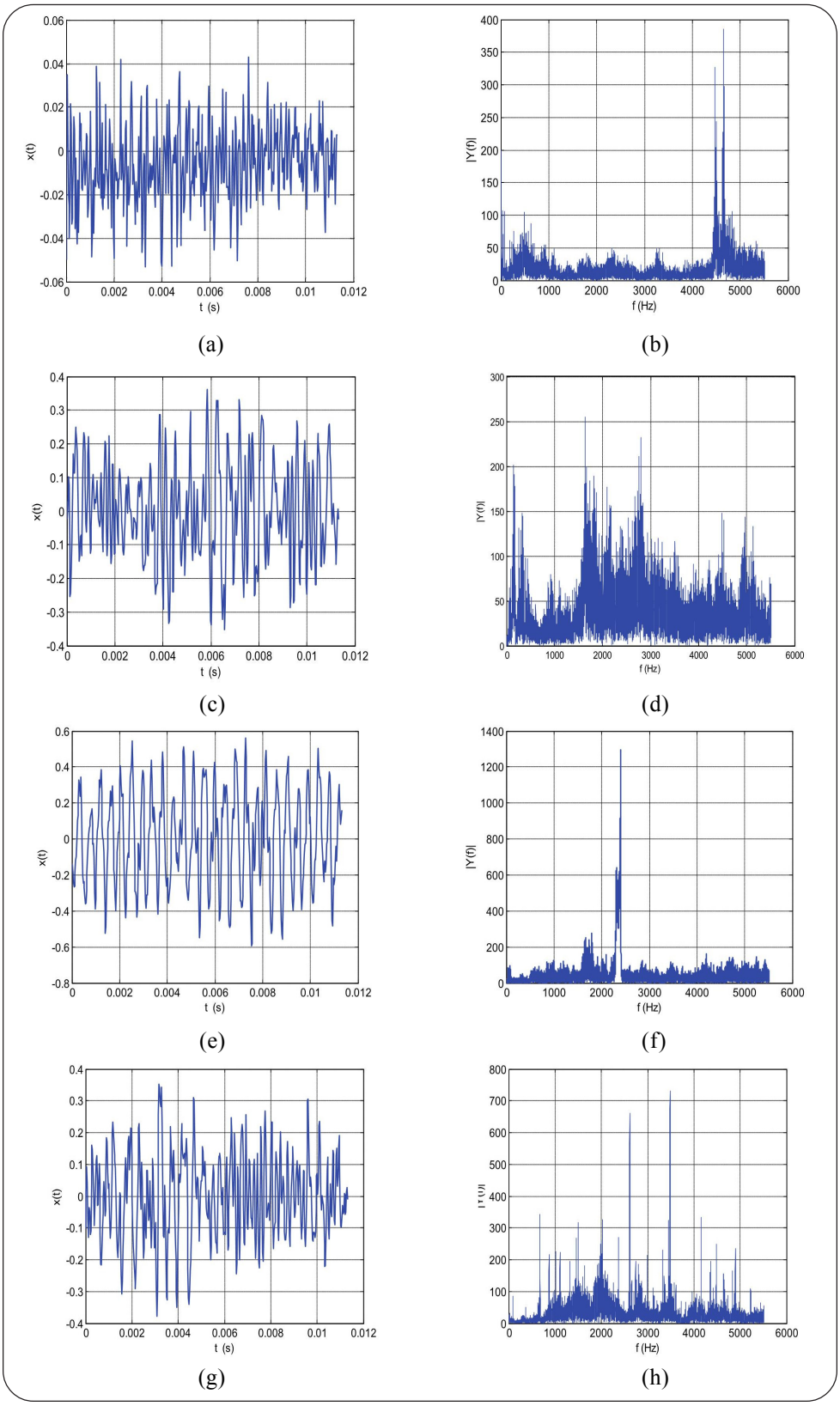


Figure 3. Time and spectral characteristic Industrial noise: Hilti for concrete a) and b); Drill for concrete c) and d); Drill e) and f); Sander g) and h) respectively

Type of noise	Intelligibility (%)				
	N	V	Nu	A	O
Drill	90.31	86.73	86.73	73.98	83.16
Sander	90.31	75.51	73.47	67.35	73.47
Drill for concrete	72.45	68.88	74.49	62.75	64.80
Hilti for concrete	72.45	56.12	67.35	45.92	59.69

Table 2. Intelligibility of word

SNR [dB]	Intelligibility [%]					
	N	V	Nu	A	O	S
10	92.86	89.89	92.86	78.57	89.89	75
5	89.89	96.43	96.43	85.71	100	71.43
0	92.86	78.57	89.89	82.14	82.14	64.29
-2	82.14	78.57	82.14	60.71	67.86	35.71
-5	75	60.71	85.71	42.86	57.14	14.28
-10	50	21.43	21.43	7.14	21.42	0
-15	25	3.57	3.57	0	0	0

Table 3. Intelligibility of speech in presence industrial noise - hilti for concrete

SNR [dB]	Intelligibility [%]					
	N	V	Nu	A	O	S
10	92.86	100	96.43	96.43	100	85.71
5	85.71	92.86	96.43	96.43	92.86	71.43
0	92.86	78.57	78.57	92.86	71.43	39.29
-2	89.89	85.71	78.57	60.71	82.14	35.71
-5	89.89	78.57	78.57	64.29	75	39.29
-10	60.71	35.71	57.14	25	28.57	7.14
-15	31.14	7.14	35.71	3.57	3.57	0

Table 4. Intelligibility of speech in presence industrial noise –drill for concrete

SNR [dB]	Intelligibility [%]					
	N	V	Nu	A	O	S
10	92.86	96.43	96.43	92.86	92.86	85.71
5	96.43	100	96.43	92.86	92.86	82.14
0	96.43	100	92.86	92.86	100	85.71
-2	96.43	96.43	89.89	75	89.89	71.43
-5	100	82.14	92.86	85.71	78.57	60.71
-10	92.86	89.89	92.86	75	82.14	60.71
-15	57.14	42.86	42.86	32.14	46.43	25

Table 5. Intelligibility of speech in presence industrial noise - drill

• *'Verb' is best for* 5 i 0dB for Drill (100%) *and the worst for* -15 dB for Hilti for concrete (3.57%),

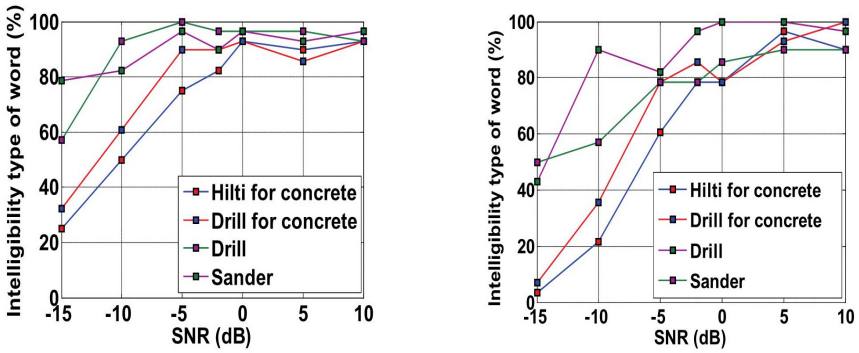
SNR [dB]	Intelligibility [%]					
	N	V	Nu	A	O	S
10	96.43	89.89	92.86	92.86	92.86	78.57
5	92.86	89.89	92.86	78.57	75	57.14
0	96.43	85.71	75	78.57	85.71	57.14
-2	89.89	78.57	78.57	64.29	71.43	42.86
-5	96.43	78.57	67.86	57.14	78.57	39.28
-10	82.14	57.14	67.86	60.71	67.86	28.57
-15	78.57	50	46.43	39.28	57.14	17.86

Table 6. Intelligibility of speech in presence industrial noise- sander

Type of noise		SNR [dB]	Intelligibility [%]					
			N	V	Nu	A	O	S
Idustrial	H	0	92.86	78.57	89.89	82.14	82.14	64.29
	Dc		92.86	78.57	78.57	92.86	71.43	39.29
	D		96.43	100	92.86	92.86	100	85.71
	Sa		96.43	85.71	75	78.75	85.71	57.14
Gaussian [8]			63.33	50	70	63.33	53.33	20
Babble [5]			53.33	36.67	53.33	46.67	30	6.67
Idustrial	H	-2	82.14	78.14	82.14	60.71	67.71	35.71
	Dc		89.89	85.71	78.57	60.71	82.14	35.71
	D		96.43	96.43	89.89	75	89.86	71.43
	Sa		89.89	78.57	78.57	64.29	71.43	42.86
Gaussian [8]			66.67	40	63.33	60	53.33	20
Babble [8]			40	10	36.67	20	16.67	6.67
Idustrial	H	-5	75	60.71	85.71	42.86	57.14	14.28
	Dc		89.86	78.57	78.57	64.29	75	39.29
	D		100	82.14	92.86	85.71	78.57	60.71
	Sa		96.43	78.57	67.86	57.14	78.57	39.28
Gaussian [8]			46.67	16.67	53.33	56.67	33.33	0
Babble [8]			26.67	6.67	10	3.33	6.67	0

N-Number, V- Verb, Nu-Number, A-Adjective, O-Object, S-Sentence,
H-Hilti for concrete, Dc-Drill for concrete, D-Drill, Sa- Sander

Table 7. Intelligibility of speech in the presence of industrial, gaussians and babble noise



(a) (b)

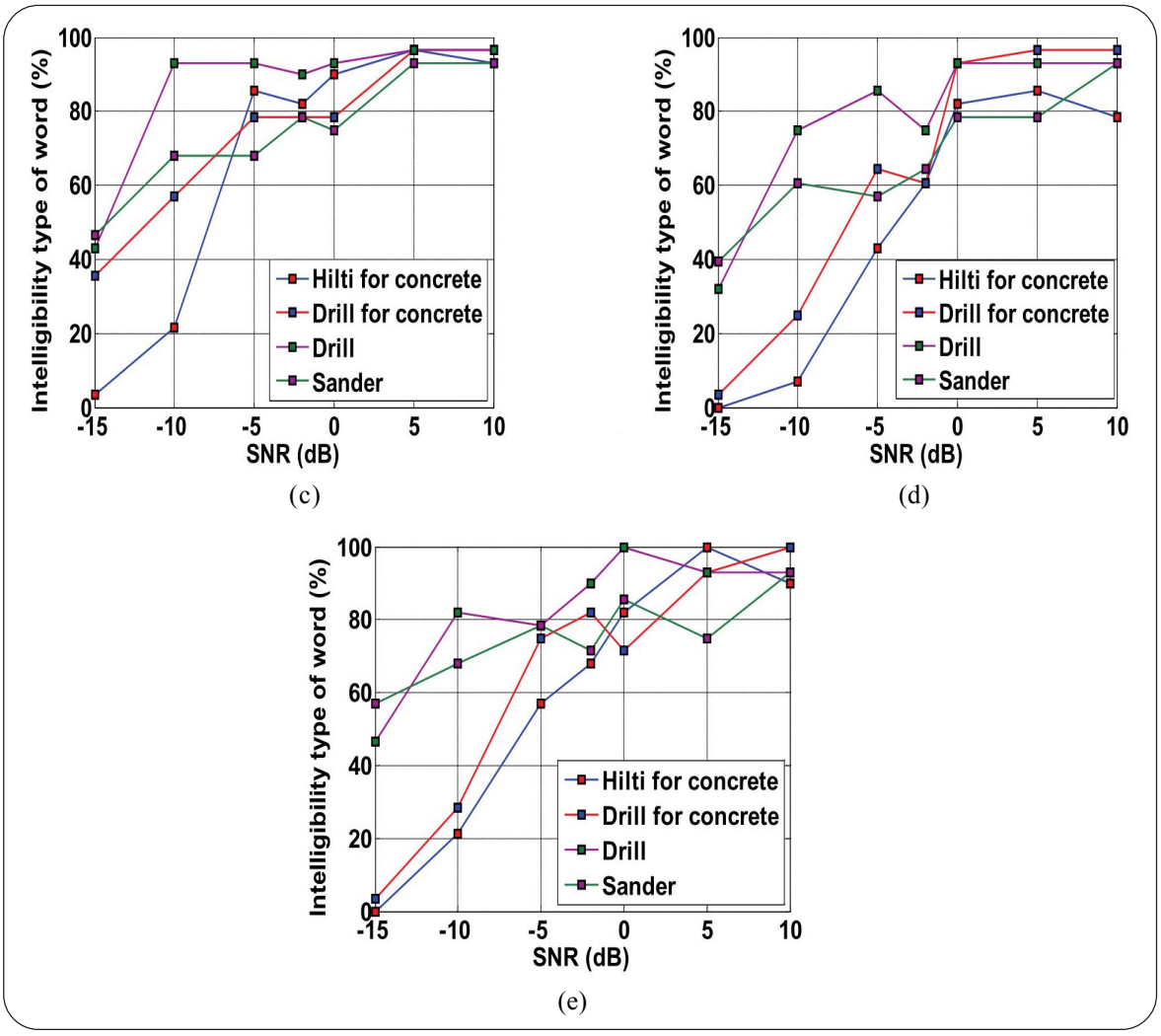


Figure 4. Intelligibility of speech for a type of word: a) Name, b) Verb, c) Number, d) Adjective and e) Object

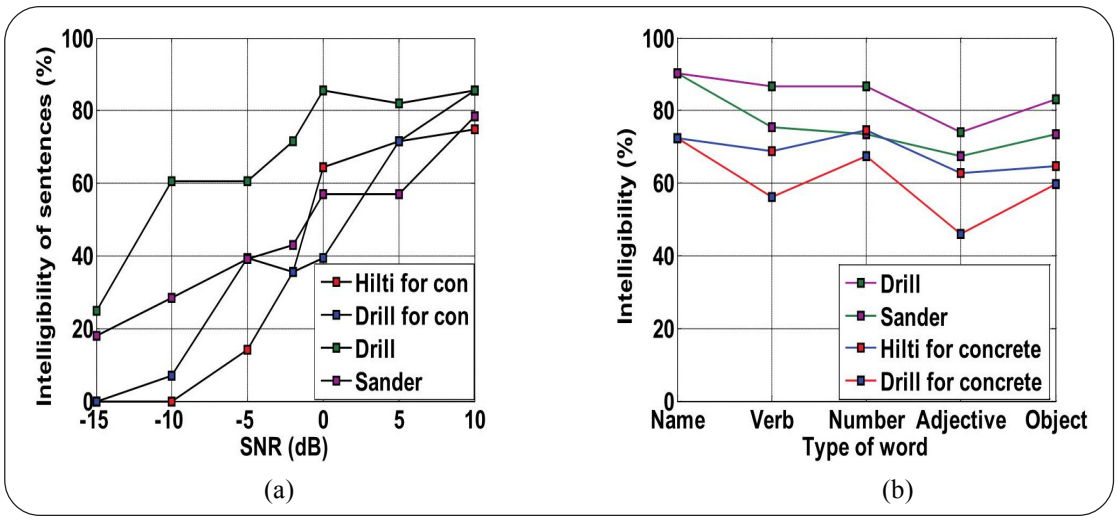


Figure 5. Intelligibility of speech for: a) sentences and b) word

• *'Number' is best for* 10 i 5 dB for Drill and Drill for concrete and 5dB for Hilti for concrete (96.43%), *and the worst for* -15 dB for Hilti for concrete (3.57%),

• *'Adjective' is best for* 10 i 5dB for Drill for concrete (96.43%) *and the worst for* -15 dB for Hilti for concrete (0%),

• *'Object' is best for* 10, 5 i 0dB for Drill for concrete, Hilti for concrete *and Drill respective* (100%), *and the worst for* - 15 dB for Hilti for concrete (0%),

Based on the results shown in Table 2 and Figure 5b it can be concluded that intelligibility of word: *'Name'* is the best 90.31% for Drill and Sander and *'Adjective'* the worst for 45.92% for Hilti for concrete.

Based on the results shown in Table 3 ÷ 4 and Figure 5a it can be concluded that intelligibility of sentence: is best for 10, 5 i 0dB (85.71%) for Drill and Drill for concrete and the worst for -10 i -15 dB (0%) for Hilti for concrete and -15 dB (0%) Drill for concrete.

By performing comparative analysis with IEC 60268-16: 2011, comes the conclusion that the intelligibility of sentences (0 ÷ 85.71%), and word (3.57 ÷ 100%) is in range from bad to excellent, depending on the value of the SNR.

Analysis the results shown in Table 7, it can be notice, that is intelligibility of speech is significantly better in the presence of Industrial noise than in Gaussian and Babble noise. The best intelligibility of speech is at Industrial, and the lowest at Babble Noise. This is the expected result when comparing the energy distribution in the spectrum Industrial, Gaussian and Babble noise.

4. Conclusion

The aim of the paper is evaluation influence various types of Industrial noise, for value SNR = -15÷10 dB, on the performance of speech intelligibility SMST. The results of tests are shown that the success of intelligibility of speech goes in range for: a) type of words: Name (25 ÷ 100%), Verb (3.57 ÷ 100%), Number (3.57 ÷ 100%), Adjective (0 ÷ 96.43%), Object (0 ÷ 100%), b) word (no matter of type) 50.97 ÷ 78.06% and c) sentence from 0 ÷ 85.71%. Based on the results it can be concluded that Industrial noise does not affect significant to the intelligibility of the speech signal as Gaussian and Babble noise.

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