INFLUENCE OF THE RAIN NOISE TO INTELLIGIBILITY IN SERBIAN LANGUAGE

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Abstract

*The first part of the paper describes the intelligibility of speech, influence of rain noise (**RN**) and the signal to noise ratio (**SNR**). The second part of the paper presents the results of testing word and sentence spoken on the Serbian language generate from Serbian Matrix Sentence Test (**SMST**) base. The testing was performed: a). using subjective MOS test, on test group in the Collage of Applied Science of Niš, and b). objective STOI test, using STOI algorithm. Results of testing were shown in tabular and graphical form. After a comparing the results with the results of similar tests with Gaussian noise, the conclusion has been brought.*

Keywords: Intelligibility, Rain noise, Gaussian noise, STOI, MOS.

1. INTRODUCTION

Speech is a way of communication between people. It is the process created by voice organs in the form of articulated voice symbols. In the speech communication process, which is reversible process, there are: the source that sends the message and the recipients who receives the message and from whom the response is expected. During the transmission of a voice (audio) message through a communication channel, there may be interference, which can have influence on speech intelligibility.

The measure, of how speech is intelligible in given conditions, is intelligibility, expressed in percent. The intelligibility depends on: level and quality of the speech signal, the type and level of background noise and for speech over communication devices, the properties of the communication system.

The noise can take many forms like: traffic on the street, aircraft noise, sirens or sounds like hammers, drills and natural sounds like wind, rain or ocean waves, many people talking at the same time (babble noise), reverberations in a space, production elements like laugh and music, and equipment problems like hum and distortion ... Whatever form the noise takes, it will have influence to intelligibility when noise falls in the same frequency range as the consonants of speech.

The rain noise contains all the frequencies that we can hear. From a comprehensive investigation done by Lee, it is discovered that the impact from rain noise can be categorized as the irritating noise causing disturbance and annoyance [1].

This paper is analyze how rain noise (RN) have influence on the intelligibility of speech, gives an evaluation the intelligibility of words and sentences from SMST [2] and also the effectiveness of the STOI algorithm with optimal parameters (Nopt, βopt) described in paper [3], for SNR = {-5, -2, 0, 2, 3, 5} dB.

The experiment was performed at the Collage of Applied Science in Niš, using form of: a). subjective MOS test and b). An objective test (STOI algorithm). MOS tests were implemented on test group of students the Collage of Applied Technical Science of Niš, age from 18 to 24 years. The intelligibility word and sentences, spoken in the Serbian language was determined with MOS test, and the results are used as a reference for the purpose of comparing the results obtained with the STOI algorithm. By comparing the results of similar tests, a conclusion was made on the intelligibility of speech.

The organization of work is the follow. Section 2 describes the relation between rain noise, Gaussian noise and SNR. Section 3 describes an experiment and an evaluation of

intelligibility words and sentence from SMST base, and performs comparative analysis of the results. Section 4 is a conclusion.

2. RAIN NOISE

The rain noise contains all the frequencies (high, medium and low pitch sounds) at equal amplitudes. Because of this, it has a similarity with Gaussian noise. Although they are similar, the rain noise has advetige over Gaussian noise, because it is natural sound. The rain have intensity witch is definition in MS IEC 60721-2-2 2004 and it was shown in table 1 [4].

Table 1. Classification of rain intensity according MS IEC 60721-2-2 2004

Rainfall type	Rainfall Rate [mm]
Moderate	Up to 4
Intense	Up to 15
Heavy	Up to 40
Cloudburst	Greater than 100

Fig.1. is show: a). time and b). spectral characteristic of rain noise.

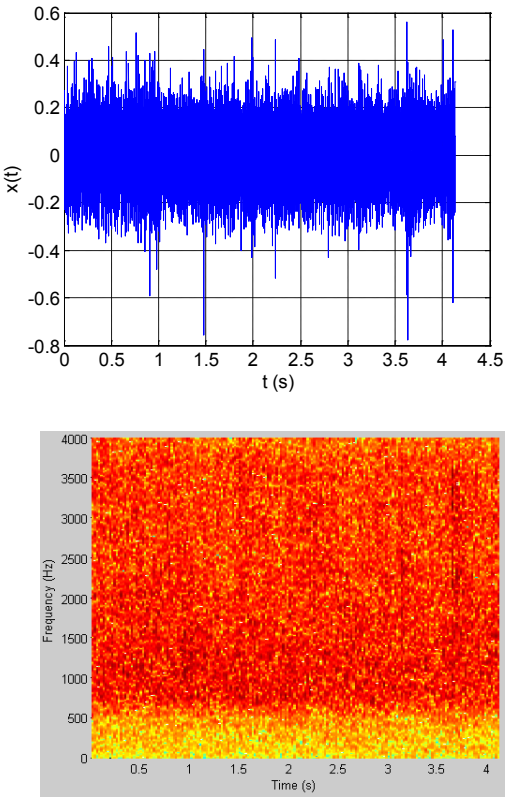


Fig. 1. *The characteristic of rain noise: a). time and b). spectral.*

Gaussian noise is statistical noise having a probability density function (**PDF**) equal to that of the normal distribution, which is also known as the Gaussian distribution. In other words, the values that the noise can take on are Gaussian distributed [3].

A special case is white Gaussian noise. White noise according definition from Princeton University is the random signal (or process) with a flat power spectral density. In other words, the signal contains equal power within a fixed bandwidth at any center frequency. In communication channel testing and modeling, Gaussian noise is used as additive white noise to generate additive white Gaussian noise.

The Signal to Noise Ratio (**SNR**) is one of the main signal characteristics in signal modeling process. It expresses the difference in decibels between the level of speech and background noise. To ensure excellent intelligibility this difference is recommended to be 10÷15dB minimum for people with good hearing, and 20÷30dB for hearing impaired or users of heat-seat [6]. A local SNR of 30dB is effectively a clean signal. Listeners will barely notice anything better than 20dB, and intelligibility is still pretty good at 0dB SNR (speech energy and noise energy the same). These numbers depend on the type of noise; competing speech or babble is the most disruptive for a given energy, since it matches the spectral distribution (and modulation dynamics) of the target speech. Conventional speech recognizers are much more sensitive than listeners, and typically show significantly increased word error rates at 20dB SNR.

If you want to estimate the SNR of a speech signal that already has noise added, you can exploit the property of speech containing many silent gaps to obtain 'glimpses' of the background noise alone. Assuming stationary noise, this then allows you to estimate the background noise level, and thus the total SNR [7]. This is the basis of the SNR estimation procedure developed by Hans-Gunter Hirsch and described in ICSI Technical Report 93-012 [8]. The Table 2 represented indicative levels of speech intelligibility related to SNR [6].

Table 2. Indicative levels of speech intelligibility related to SNR [6]

People with good hearing	SNR [dB]	Hearing impaired or users of head -sets
-	30	Excellent
-	20	Good
Excellent	15	Fair
Good	10	Marginal
Fair	5	Poor
Marginal	0	No intelligibility
Poor	-5	
No intelligibility	-10	

3. EXPERIMENTAL RESULTS AND ANALYSIS

This section, described experiment of intelligibility in the presence of RN. The results are shown in tabular and graphical form.

3.1. EXPERIMENT

Realization an experiment, for testing the intelligibility of word and sentences from SMST base, in the presence of the Rain noise, it is required to perform the following steps:

1. Select a random sentence from the SMST base using the computer,
2. Generate a noise signal type RN from the base of noise,
3. Change the predefined values of SNR to the generated noise signal,
4. Testing the test group with MOS test, and realize a STOI test.

The block diagram shown on Fig.2

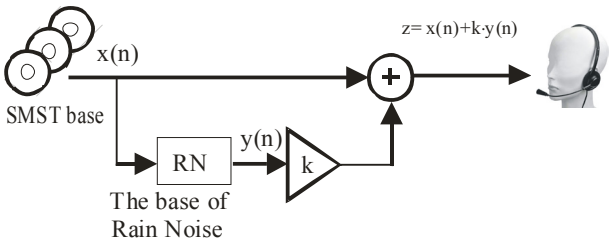


Fig. 2. *Block diagram of generated signal **z,** used for testing intelligibility with MOS and STOI tests.*

Fig. 2. represented the block diagram generated signal ***z***. Signal ***x(n)*** are the pure speech signal, and ***y(n)*** are signal of rain noise. Coefficient for determinated value of SNR is marked with ***k***.

3.2. BASE

Speech material using for testing was generated from a SMST base described in [2]. The words from the SMST base are spoken in Serbian language. Selections of the word from the SMST base using the random law by the computer, the sentences with a fixed syntax structure were formed. The syntax structure is in this order: name-verb-number-adjective-object. Every time, the sentence is different, which made test unpredictable for the tested group. Frequency of sampling is Fs = 8kHz. The example one of the tested sentences without noise (original signal) "Slaviša briše devet novih stolova" is given on Fig 3. The signal of rain noise was generated through the program Matlab, from base of the Rain noise. The classification of rain intensity, according MS IEC 60721-2-2 2004 (shown in Table 2), using in this test is "Intense".

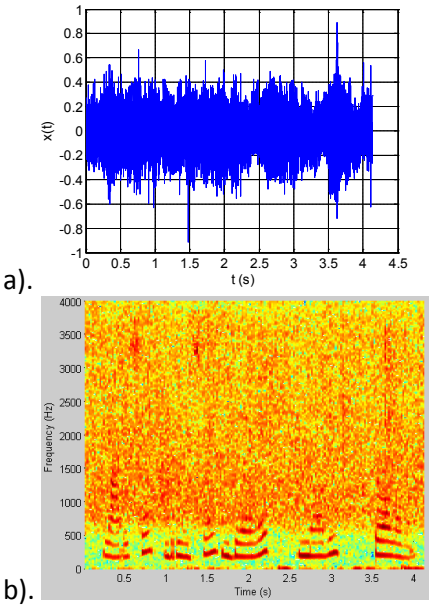


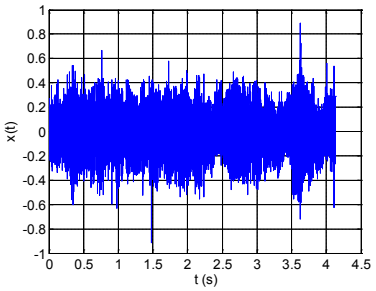
Fig. 3. *The characteristic of the speech signal "Slaviša briše devet novih stolova": a). time and b). spectral.*

3.3. TEST GROUP

Test group was formed from students (10 men and 10 woman) of the Collage of Applied Science Nis, age from 18 to 24 (mean age μ = 20.65 years). All tested reported that they are not aware of any hearing problems. Testing was performed using headphone. After reproduced generated sentence, examinee

repeated aloud a sentence that he/she thought he/she had heard. The response was written by examiner in the column of word and sentence. The example one of the tested sentences "Slaviša briše devet novih stolova" with the presence of Rain noise is given on Fig. 4.

a).



b).

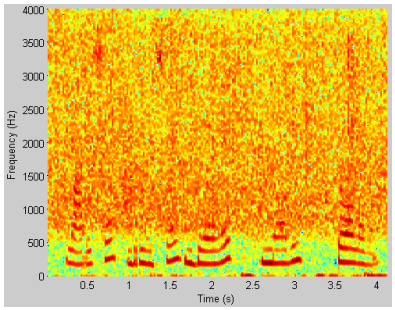


Fig. 4. *The characteristic of the speech signal with rain noise: a). time and b). spectral*

3.4. RESULTS

Table 3, shows the results of MOS test and STOI test (dSTOI coefficient) for type of word: N - Name, V - Verb, Nu-Number, A - Adjectiv, O - Object. In the table 4 results of MOS test and also a dSTOI coefficient for whole sentence are shown.

In the Fig.5. are shown intelligibility determinated with a subjective MOS test for the words. The values of the intelligibility sentence determenited by: a) MOS and b). STOI test for SNR = {-5, -2, 0, 2, 3, 5} dB are shown graphically on Figs. 6. Mean value of word and sentence in the presence of: a). RN and b). Gaussian noise (**GN**) [9] is shown on Fig.7. The comparative results for dSTOI for RN and White Gaussian Noise (**WGN**) [3] are shown graphically in Fig.8.

Table 3. Intelligibility of type of word in the presence of RN

SNR [dB]	Intelligibility [%]				
	N	V	Nu	A	O
5	87.5	77.5	82.5	75	75
3	87.5	80	92.5	77.5	75
2	92.5	85	90	55	75
0	87.5	85	82.5	57.5	82.5
-2	90	85	85	72.5	92.5
-5	72.5	70	65	55	70

Table 4. Intelligibility of sentence in the presence of RN

SNR [dB]	Intelligibility [%]	
	WS	dSTOI
5	37.50	76
3	42.50	74
2	42.50	72
0	35.00	69
-2	50.00	68
-5	20.00	63

In the Table 5, it was given results of intelligibility speech signal from SMST base with Gaussian Noise [9].

Table 5. Intelligibility of speech in the presence of RN and GN [9] (MOS test).

Mean value	Intelligibility [%]					
	N	V	Nu	A	O	WS
RN	60	42,5	65,83	64,17	53,33	12,50
GN	43.75	30.83	44.17	38.75	37.50	43.75

Table 6. Intelligibility of speech in the presence of GN [9]

SNR [dB]	Intelligibility [%]					
	N	V	Nu	A	O	WS
2	63	63.3	76.	76.6	73.3	26.6
0	63	50	70	63.3	53.3	3.33
-2	66	40	63.	60	53.3	20
-5	46	16.6	53.	56.6	33.3	0

Table 7. Intelligibility of sentence in the presence of RN and WGN [3] - STOI test

dSTOI	Intelligibility sentence for SNR [%]			
	-5dB	-2dB	0dB	2dB
RN	63.00	68.00	69.00	72.00
WGN	45.088	61.55	66.52	70.20

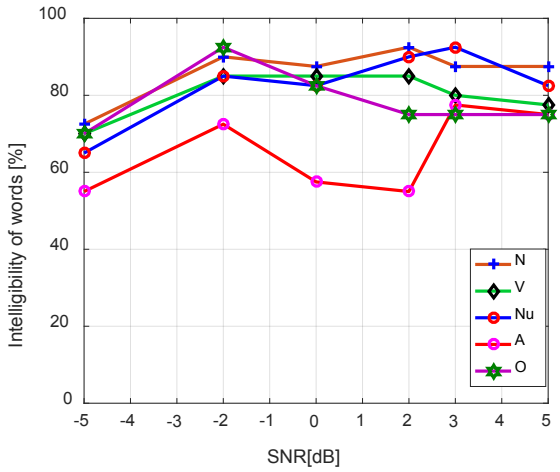


Fig. 5. *Intelligibility of words MOS test*

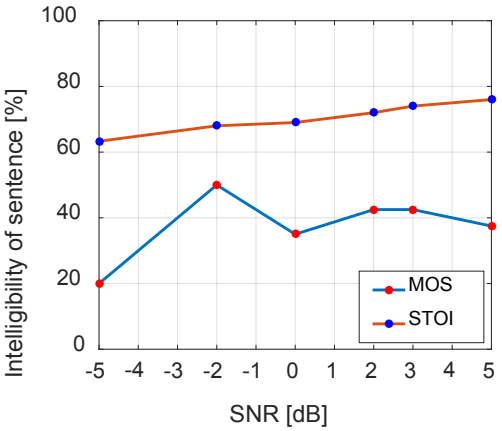


Fig. 6. *Intelligibility of sentence MOS and STOI test*

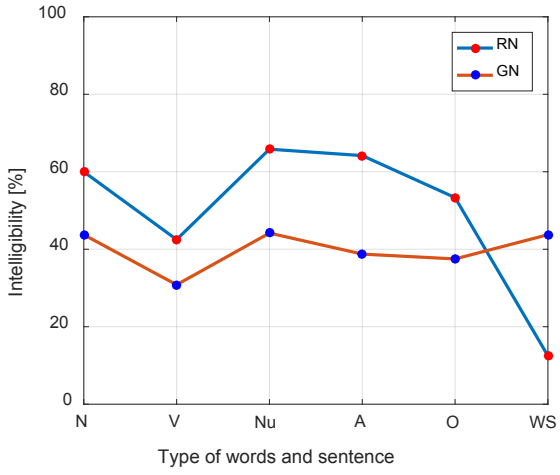


Fig. 7. *Mean value intelligibility of word and sentences in the presence of Rain noise (RN) and Gaussian noise (GN).*

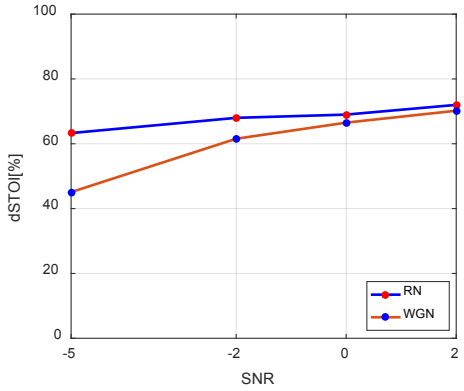


Fig. 8. *Coefficient dSTOI for intelligibility of sentences in the presence of Rain noise (RN) and Gaussian noise (GN).*

3.5. ANALYSIS OF RESULTS

Based on the results shown in Table 3 and Fig. 5. It can be concluded that intelligibility of type of word:

a) 'Name' is best for 2dB (92.5%), and the worst for -5dB (72.5%),

b) 'Verb' is best for -2, 0 and 2dB (85%) and the worst for -5 dB (70%),

c)'Number' is best for 3 dB (92.5%), and the worst for -5 dB (65%),

d)'Adjective' is best for 3dB (77.5%), and the worst for 2 and -5 dB (55%),

e)'Object' is best for -2dB (92.5%), and the worst for -5 dB (70%),

Based on the results shown in Table 4 and Fig. 6 it can be concluded that intelligibility of sentence is:

a). best for -2dB (50%) and the worst for -5 dB (20%), for MOS test;

b). best for 5dB (76%) and the worst for -5 dB (63%), for STOI test (dSTOI coefficient).

Based on the results shown in Table 5 and Fig.7 it can be concluded that intelligibility of word: 'Number' is the best 65.83% and 'Verb' the worst for 42.5%.

Using comparative analysis with IEC 60268-16: 2011, the conclusion of intelligibility is:

a). bad (0÷89%) for sentences (20 ÷ 50%),

b). in range from poor (67÷78%), and fair (78÷87%) to good (87÷94%) for words (55 ÷ 92.5%),

depending on the value of the SNR.

Comparing with the results shown in Table 6÷7, and Fig. 7÷8, it can be notice, that is intelligibility of speech is better in the presence of Rain noise then the Gaussian noise.

4. CONCLUSION

The aim of the paper is an evaluation influence of Rain noise (RN), for value SNR = {-5, -2, 0, 2, 3, 5} dB, on intelligibility of words and sentences from SMST base. Test results show that the intelligibility of speech is in range from poor to good for words, and bad for sentences. These results fully correspond the indicative levels of speech intelligibility related to SNR, for 5 dB [6].

Based on the results it can be concluded that rain noise (RN) does not affect to the intelligibility of the speech signal as Gaussian noise. The explanation for this can be found in the power of spectral density of rain noise and in the fact that the RN is natural sound.

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