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The influence of rain and thunder on speech intelligibility

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Abstract

In this paper, an evaluation of the influence of noise caused by rain and thunder on the intelligibility of sentences from the Serbian Matrix Sentence Test base (SMST) was performed. The first part of the paper describes an experiment in which the intelligibility of speech was tested by the binaural method using the objective STOI test, in the presence of reflection, diffusion noise and noise rain and thunder. The test results are presented in tabelar and graphical form. In the second part of the paper, a comparative analysis of intelligibility was performed with the results of similar tests. The conclusion of intelligibility was brougth using international standard IEC 60268-16:2011.
Keywords: *intelligibility, noise, rain, thunder, SMST base, STOI.*

1. Introduction

To achieve successful communication between people, whether it is through means of communication (mobile phones, radio connections, etc.) or direct contact in different spatial environments it is important to achieve good intelligibility of speech. To many factors affect on intelligibility. When it comes to communication systems, it is usually means on the width of the frequency range, distortions in the transmission system... while when it comes to spatial acoustics, it means on the appearance of different types of ambient noises (babble (Kostić et al., 2019), industrial (Milivojević et al., 2016), rain (Kostić et al., 2018), wind (Milivojević et al, 2018)…), as well as the reverberation time of the room, the ratio of direct and reflected sound.

Speech intelligibility can be tested by subjective and objective methods using speech material which represents types of words: a) PB list (Clark, 1981), b) logatoms (Kostić et al., 2016) or sentences: a) semantic-meaningful (Plomp&Mimpen, 1979) or b) syntax-matrix (Wagener et al., 2003), (Boboshko et al., 2013)). Subjective methods involve testing subjects with unimpaired or impaired hearing and the results are evaluated using the MOS (Mean Opinion Score) test. Objective methods use a suitable algorithm for testing, implemented by a machine, and as a result of testing we have a numerical value from 0-1 (i.e., from 0-100 expressed in percentages (%).

In aim to examine intelligibility, the authors of this paper used an objective testing method using the STOI (Short-Time Objective Intelligibility) algorithms described in the paper (Milivojević et al, 2018). Matrix sentences from the Serbian Matrix Sentence Test - SMST base (Milivojević et al, 2016) were used as test signals. An experiment was provided in which the acoustic environment was simulated where the reflected speech signal was superimposed on the speech signal x for values $\Delta t = \{0,10,25,50\}$ms. After that, diffuse noise DN and rain noise with thunder RTN were added. The SNR values for both noises have been changed. Values of SNR= {0, -2, -5} dB. An objective intelligibility test was performed on the test signal using the STOI algorithm using the binaural method. The test result is the dSTOI intelligibility coefficient for the left and right ear. The results are presented tabularly and graphically. Intelligibility is expressed as a percentage in the range of 0 - 100%, and the intelligibility classification is based on the standard IEC 60268-16: 2011. After that, a comparative analysis of the results with the comprehensibility of similar degradations was performed. The

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paper is structured as follows: In section II, the experiment is described, the results were presented and a comparative analysis was performed. Section III is the conclusion.

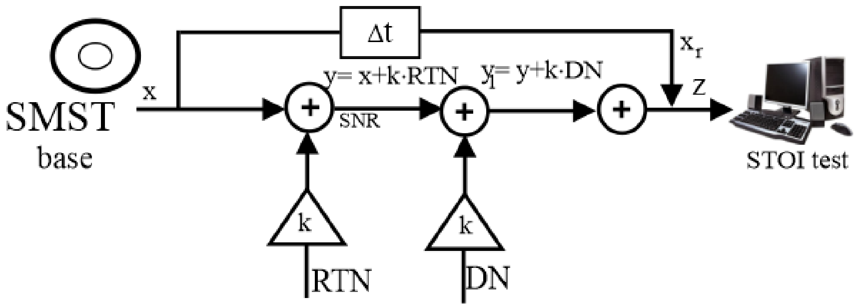
2. Experimental results and analysis

Experiment

The examination influence of noise which provide rain with thunder on intelligibility using the binaural method, was performed on the way shown on Fig. 1. For the purposes of the experiment, a sentence was generated from the SMST base. After that, a sentence of the reflected signal is created with early reflections for ***Δt={0,10,25,50}ms***. Then the diffusion noise and noise obtained by combining rain and thunder are superimposed on the reflected signal, for predefined values of ***SNR ={ 0,-2,-5}dB***. The test signal generated in this way is tested using the STOI algorithm, for two cases: a) when the SNR value of diffuse noise and rain and thunder noise is equal, $SNR_{DN} \neq SNR_{RTN}$ and b) when the SNR value of diffuse noise and rain and thunder noise is different $SNR_{DN} \neq SNR_{RTN}$. The results were obtained for the left and right ear separately and are expressed through the dSTOI coefficient in percentage (%).

The parameters used in the experiment are: a) the excitation angle of the speech signal $\phi x = 0°$; b) excitation angle of the reflected signal $\phi r = 0°$; c) diffuse noise angle $\phi DN = 0 : 5 : 360°$, d) reflection amplitude $Ar = 1$.

Figure 1. Block diagram of experiment.



Source: Authors´s research

Speech signal base

For testing purposes, speech signals-sentences from the SMST base described in the work (Milivojević et al, 2016) were generated. Using the method of random selection, a sentence with a precisely defined syntax structure was formed: name, verb, adjective, number and noun. For the purposes of the experiment, 200 different sentences were created. An example of one of them is given in Figure 2.

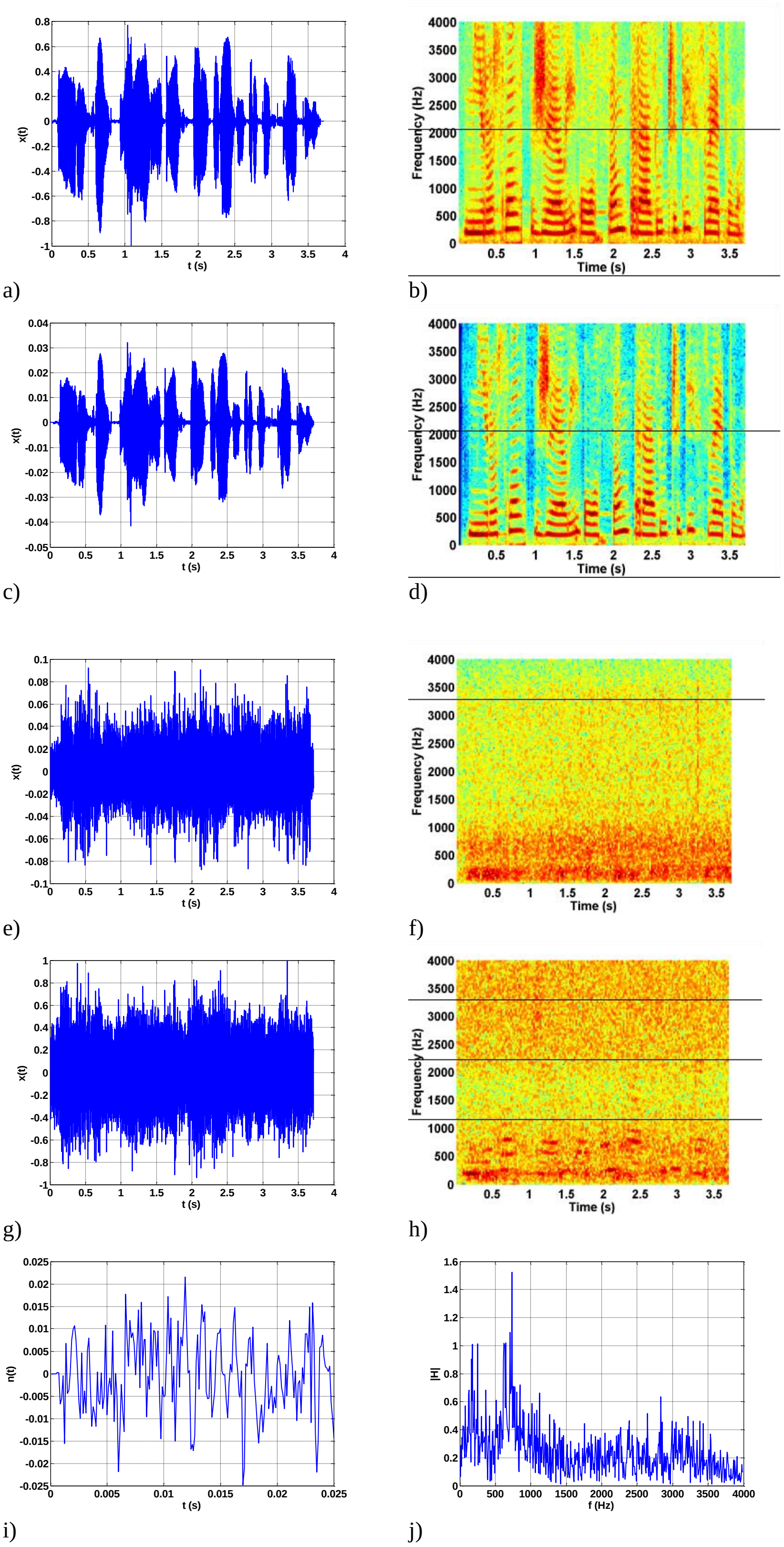
Base of noise

Rain is a sound from nature that serves to mask background noise, i.e., signals. The sound of rain contains all types of frequencies with the same amplitude, so its characteristic resembles Gaussian noise. Rain can be classified according to MS IEC 60721-2-2 2004, described in more detail in the paper (Kostić et al., 2018).

Thunder is a sound phenomenon that occurs as a result of an atmospheric discharge (lightning). It represents a mixture of different frequencies, with a speed of about 300m/sec.

To create a noise, for the purposes of the experiment, rain signals and thunder signals taken from the sound base https://mixkit.co/free-sound-effects/and combined in the program Matlab. The time form of the noise formed in this way are shown in Figure 2e, while the spectrogram is shown in Figure 2f.

Figure 2.Time and spectral characteristic of : a and b speech signal, c and d reflected speech signal, e and f rain and thunder noise, g and h genereted test signal



Source: Authors´ research

The results

The results of the experiment are presented in tables 1- 4 and in Figure 3-4. Tables 1 and 2 are show the results for the left and right ear, for the condition SNR_{DN}=SNR_{RTN}, while Tables 3 and 4 show the results for the left and right ear, for the condition SNR_{DN}≠SNR_{RT}N. Figure 3-4 shows the mean value of intelligibility observed from the aspect of ***Δt(ms)*** and for the conditions SNR_{DN}=SNR_{RTN}, SNR_{DN}≠SNR_{RTN}.

Table 1. Intelligibility for left ear, for SNR_{DN}=SNR_{RTN}

	dSTOI$_L$ (%)		
Δt(ms)/SNR (dB)	0	-2	-5
0	66,14	60,88	55,34
10	57,80	54,29	47,36
25	57,46	51,50	48,32
50	49,23	50,11	45,37

Source: Authors´ research

Table 2. Intelligibility for right ear, for SNR_{DN}=SNR_{RTN}

	dSTOI$_R$ (%)		
Δt(ms)/SNR (dB)	0	-2	-5
0	66,58	61,47	55,28
10	58,40	53,97	48,25
25	58,01	51,76	48,27
50	58,29	50,58	55,53

Source: Authors´ research

Table 3. Intelligibility for left ear, for SNR_{DN}≠SNR_{RTN}

	dSTOI$_L$ (%)	
Δt(ms)/SNR (dB)	-2	-5
0	64,31	60,91
10	56,51	51,61
25	53,19	50,73
50	56,08	47,24

Source: Authors´ research

Table 4. Intelligibility for right ear, for SNR_{DN}≠SNR_{RTN}

	dSTOIR (%)	
Δt(ms)/SNR (dB)	-2	-5
0	64,51	61,10
10	56,59	51,74
25	53,30	50,28
50	50,36	47,12

Source: Authors´ research

Figure 3. Mean value intelligibility for SNR_{DN}=SNR_{RTN}

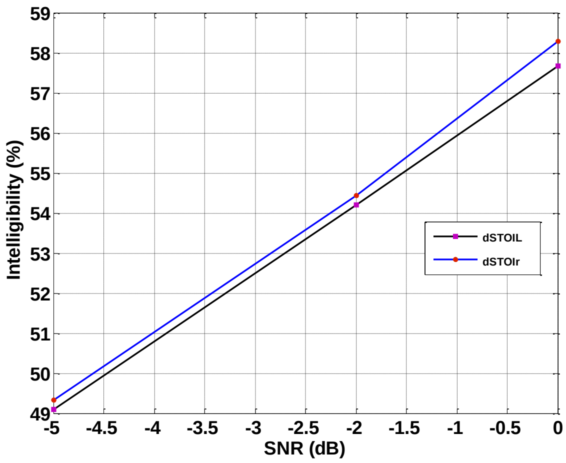


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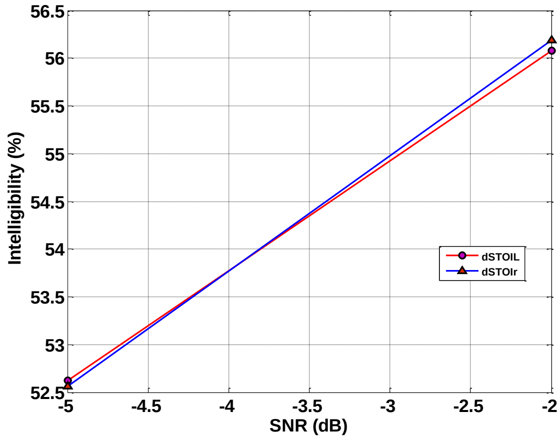
Figure 4.Mean value intelligibility for $SNR_{DN} \neq SNR_{RTN}$



Source: Authors´ research

Analysis of results

Analyzing the obtained results of the experiment shown in tables 1 - 4 and Figure 3-4, for Δt = {0, 10, 25, 50} ms, the following observations about intelligibility are made:

a) for SNR = -2dB from 53,19 – 64,31%, the left ear and from 50,36 – 64,51%, the right ear ($SNR_{DN} \neq SNR_{RTN}$),
b) for SNR = -5dB from 47,24 – 60,91%, the left ear and from 47,12-61,10%, the right ear ($SNR_{DN} \neq SNR_{RTN}$),
c) for SNR = 0dB from 49,23 – 66,14%, the left ear and 58,01 -66,58%, the right ear ($SNR_{DN} = SNR_{RTN}$),
d) for SNR = -2dB from 50,11 – 60,88%, the left ear and from 50,58 – 61,47%, the right ear ($SNR_{DN} = SNR_{RTN}$),
e) for SNR = -5dB of 45,37 – 55,34%, the left ear and of 48,25 – 55,53%, the right ear ($SNR_{DN} = SNR_{RTN}$)

Analyzing the results shown for the mean value in Figure 3-4 for SNR = {-5, -2, 0} dB, without observing the time of delay, it is concluded that the intelligibility of speech for:

a) SNR = 0dB is 57,66%, the left ear and 58,29%, the right ear ($SNR_{DN} = SNR_{RTN}$),
b) SNR = -2dB is 54,20%, left ear and 54,44%, right ear ($SNR_{DN} = SNR_{RTN}$),
c) SNR = -5dB is 49,10%, left ear and 49,33%, right ear ($SNR_{DN} = SNR_{RTN}$),
d) SNR = -2dB is 56,08%, left ear and 56,19%, right ear ($SNR_{DN} \neq SNR_{RTN}$),
e) SNR = -5dB is 52,62%, left ear and 52,56% right ear ($SNR_{DN} \neq SNR_{RTN}$).

3. Conclusion

Comparing results of intelligibility with standard IEC 60268-16 it can be concluded that the intelligibility belongs to the classification of bad intelligibility (0-89%). Using a comparative analysis with the results of similar tests (Kostić et al., 2018) it can be concluded that intelligibility is better for RTN noise, than for rain or white Gaussian noise by -5dB. Also, it can be notice that the intelligibility is better for rain noise. The answer is in the spectral caracteristic, as well as that the rain and thunder are natural noise.

As with earlier tests conducted to evaluate intelligibility, using the binaural method, it is again confirmed the better intelligibility of the speech signal that a person receives on the right ear than on the left, both for individual results and for the mean value.

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